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HYDROLOGY ANALYSIS

# Sprague Lake

CITY OF SPRAGUE, WASHINGTON

October 2, 2023

Shannon & Wilson No: 109828-008

SHANNON & WILSON

Submitted To: Washington State Department of Ecology
4601 North Monroe
Spokane, WA 99205-1295
Attn: Karl Rains

Subject: HYDROLOGY ANALYSIS, SPRAGUE LAKE, CITY OF SPRAGUE, WASHINGTON

Shannon & Wilson prepared this report and participated in this project as a consultant to Washington State Department of Ecology. Our scope of services was specified in Agreement Number 109828-C230071, dated November 18, 2022. This report presents the hydrologic and hydraulic analysis for Sprague Lake in Sprague, Washington, and was prepared by the undersigned.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report, or we may be of further service, please contact us.

Sincerely,

SHANNON & WILSON

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MDP:GBK:SRB/mdp

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# ACRONYMS

| | |
|---|---|
| AEP | Annual Exceedance Probability |
| ASCE | American Society of Civil Engineers |
| CEM | Coastal Engineering Manual (USACE, 2015) |
| cfs | cubic feet per second |
| CLOMR | Conditional Letter of Map Revision |
| CUP | Conditional Use Permit |
| EIS | Environmental Impact Statement |
| FEMA | Federal Emergency Management Agency |
| FIS | flood insurance study |
| GIS | geographic information system |
| Ecology | Washington State Department of Ecology |
| HEC-RAS | Hydraulic Engineering Center's River Analysis System |
| HPA | Habitat Project Approval |
| LEDPA | Least Environmentally Damaging Practicable Alternative |
| LOMR | Letter of Map Revision |
| mph | miles per hour |
| NGS | National Geodetic Survey |
| NWP | Nationwide Permit |
| QA/QC | quality assurance/quality control |
| SEPA | State Environmental Policy Act |
| SR | State Route |
| USACE | U.S. Army Corps of Engineers |
| USGS | U.S. Geological Survey |
| WDFW | Washington Department of Fish and Wildlife |
| WQC | Water Quality Certification |

# 1 INTRODUCTION

This report presents the hydrologic and hydraulic analysis for Sprague Lake in Sprague, Washington (Figure 1). The Washington State Department of Ecology (Ecology) has indicated a need for the investigation into the recent flooding events in the City of Sprague (the City) and nearby areas, and recommendations of ways to reduce flood frequency and/or duration and improve the lakefront's resiliency during high rain and wind events.

A detailed hydrology analysis was conducted to determine alternatives that serve to mitigate flooding within Sprague Lake. Our results and findings are provided herein.

Sprague Lake is a 5-mile-long water body straddling Lincoln and Adams counties in eastern Washington. The nearby City is roughly 2.5 river miles upstream of the northeast lakeshore and roughly 35 miles southwest of Spokane, Washington. Flooding has been routinely reported in the City during high water lake events, in addition to flooding reports from landowners at the northeast shoreline, and the campground along the northwest shoreline adjacent to Bob Lee Road. Ecology and the Washington Department of Fish and Wildlife (WDFW) have formed a joint technical team to supervise this project investigating the causes and potential relief options for this flooding. Ecology is the lead agency administering this contract.

Shannon & Wilson has been engaged in a contractual agreement to conduct surveying, geographic information system (GIS) analysis, and hydrological and hydraulic investigations. The primary objective of these investigations is to discern areas of lake outlet flow constriction, be they artificially constructed or naturally occurring, and subsequently explore potential conceptual enhancements aimed at mitigating or improving conditions at these constrictions.

# 2 PROJECT SITE

The project site spans from the rock outcrop at the downstream extent to the northwest confluence of Negro Creek and Sprague city limits (Figure 2).

## 2.1 Hydrology

Ecology indicated that the flow inputs to Sprague Lake and their ratios of groundwater to surface water are not well understood. It is not the intent of this project to quantify or predict the hydrologic inputs to Sprague Lake. However, it should be understood how

Sprague Lake responds to rainfall and snowmelt, and whether surface water flood flows affecting the City are attenuated or driven by the surface level of Sprague Lake.

## 2.2 Tributaries and Outfall

The City surface water is drained by a series of concrete open channels and box culverts, which roughly follow West 2nd Street and North D Street. These channels collect stormwater throughout the City and discharge it under the BNSF railway to the north into a man-made vegetated channel. This vegetated channel meanders west and crosses the BNSF railway a second time, as well as I Street to the south. The vegetated channel then transitions into a natural streambed over the remaining 2 river miles as it winds through pastureland and eventually meets the shoreline of Sprague Lake (Exhibit 2-1).

**Exhibit 2-1: City of Sprague Drainage Network**

This watercourse through the City is fed by three distinct tributaries that directly affect flooding in the City. An unnamed tributary to the northwest, draining 44 square miles, crosses I-90 and joins the man-made vegetated channel north of the BNSF railway. A second unnamed tributary to the northeast follows State Route (SR) 23 south, draining 2.8 square miles, crosses I-90 and discharges into the upstream end of the concrete channels through City. Negro Creek is the main tributary of the lake and drains 215 square miles of lakes, pasture, woodlands, and open range directly east of the City. It crosses SR 23 and transitions into the concrete channel complex. The two unnamed tributaries (2.8-square-mile North Tributary East and 43.8-square-mile North Tributary West) are dry bed and only saturated during rain events. Negro Creek can clearly be seen in aerial photography switching between surface water and subsurface flow (Exhibit 2-2).

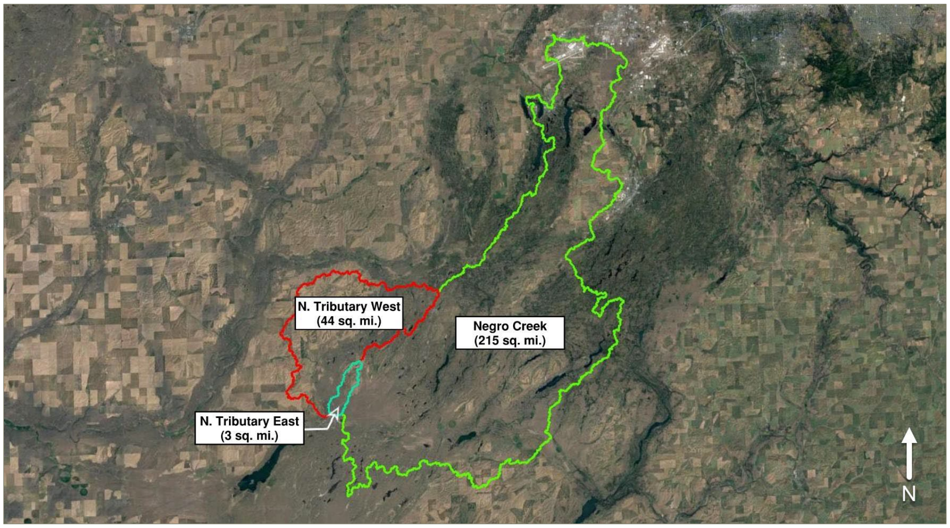


**Exhibit 2-2: Tributaries Areas at Inflow Boundaries**

Sprague Lake itself has several smaller lowland direct tributaries downstream of the City, amounting to an additional 23 square miles. These tributaries were considered negligible for the purpose of this analysis.

The outlet of Sprague Lake encompasses a relic control structure that consists of two concrete curbs positioned approximately 15 feet apart (Figure 2). These curbs retain a platform of earth and vegetation measuring approximately 1 foot in height. The flow from this control structure is directed into Cow Creek. There is a small concrete farm access crossing within Cow Creek, 1,500 feet downstream. Further downstream, approximately 3,500 feet from the farm access crossing, Cow Creek intersects with Danekas Road. At this road crossing, a skewed pipe arch culvert measuring 15 by 6.6 feet has been securely embedded into the footings using mortar, featuring a natural channel bottom. Roughly 1,800 feet downstream from Danekas Road, a prominent rock outcrop comprised of bedrock material forms a resilient natural constriction point within the channel.

## 2.3 Survey and Loggers

Shannon & Wilson was able to locate lidar, flown by NV5 Geospatial in 2018, for the entire lakeshore, downstream area, and the vicinity of the City. The lidar downstream of the lake was in an area known to be thick with vegetation, and accordingly, the returns through Cow Creek channel needed to be verified. Shannon & Wilson field staff surveyed the downstream area from the outlet structure to the rock outcrop, including the Danekas Road culvert, farm access crossing structures, and the outlet structure. Field loggers were deployed at the lake upstream of the control structure and upstream and downstream of the Danekas Road culvert. The channels in City were left consistent with the lidar surface and are expected to suffice for the level of detail needed for this study. Culvert inverts within the City were approximated based on field measurements relative to the road surface.

Water surface data loggers (SW-B, -C, and -D) were installed at three locations downstream of the lake to assess hydraulics related to the outlet to the lake and the outlet channel from the lake down to Danekas Road (Figure 2).

## 2.4 Survey Correction

The field survey was based on a U.S. Geological Survey (USGS) marker we believed to be SW1220, as detailed in the National Geodetic Survey (NGS) Database. This benchmark was occupied with our base station, which updates instruments with corrections based on satellite data throughout the day. This is standard practice for using Real-Time Kinematic survey systems. The system ran without any errors from 9:30 a.m. to 5:00 p.m. on the first day. At the end of the data collection day, the quality assurance/quality control (QA/QC) check of the data yielded a shift of 32 feet in the horizontal direction and approximately 8 feet in the vertical direction. Our Trimble survey representative verified there were no internal equipment errors, nor error messages, during the collection period. A second day of survey was needed to detail the Danekas culvert location. During this collection day, the base station was set up identically, but instead of manually locating via the NGS datasheet, field staff allowed the base station to collect data and continuously self-locate via satellite. The second day's QA/QC yielded accurate positioning of the base and topography data. This second day of data was submitted to the OPUS postprocessing online system, which confirmed the accuracy of the base station location. The first day of survey was also submitted to OPUS, which confirmed a translation of data by 32 feet in the horizontal and about 8 feet in the vertical. OPUS corrected the first day of survey and all survey data compares well with lidar for each area. It's possible that marker has been tampered with however our corrections and methodology have accounted for that possibility.

# 3 HYDROLOGIC AND HYDRAULIC ANALYSIS

## 3.1 Representative Hydrology

Two existing hydrologic data sources are available for the designated site. The hydrology data procured from the Federal Emergency Management Agency (FEMA) flood insurance study (FIS), conducted specifically for Lincoln County and the City, and the USGS StreamStats online hydrology tool are the notable sources. The two hydrologic data references exhibited concurrence concerning the occurrence of flood events with 10-year, 50-year, and 100-year return periods(as provided in the FIS). In the case of Negro Creek and the two smaller unnamed tributaries located to the north (designated as North Tributary

East and North Tributary West), the StreamStats data was employed to approximate flow rates. Exhibit 3-1 provides a comparison of peak discharges for 10-year, 50-year, and 100-year return periods between the FIS and StreamStats.

**Exhibit 3-1: Peak Discharge Comparison Summary**

| Return Period | Negro Creek | North Tributary East | North Tributary West |
|---|---|---|---|
| 2-year, FIS (cfs) | N/A | N/A | N/A |
| 2-year, StreamStats (cfs) | 654 | 24.9 | 192 |
| 10-year, FIS (cfs) | 2,250 | N/A | N/A |
| 10-year, StreamStats (cfs) | 2,240 | 111 | 738 |
| 50-year, FIS (cfs) | 4,950 | N/A | N/A |
| 50-year, StreamStats (cfs) | 4,750 | 278 | 1,960 |
| 100-year, FIS (cfs) | 6,200 | N/A | N/A |
| 100-year, StreamStats (cfs) | 6,180 | 385 | 2,260 |

cfs = cubic feet per second

The Soil Conservation Service TR-55 methodology was used to approximate the basin characteristics and times of concentration. Local rainfall data was used to compare logger lake levels with a predicted hydrograph.

## 3.2 Hydraulic Modeling

Shannon & Wilson employed the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center's River Analysis System (HEC-RAS) Version 6.3.1 to conduct our analyses. This two-dimensional model enables the examination of flow in multiple directions. Note, a one-dimensional model would not suffice for this study. Such a model would fail to consider the dispersion of flow from the area of the City through the project culverts located centrally in the City. Additionally, it would overlook the attenuation of peak flows in Sprague Lake provided by constrictions located downstream at the flow control structure and Danekas Bridge. Furthermore, the HEC-RAS software operates on a conservation of volume and conservation of mass platform, eliminating the need for subjective modeling choices, as it inherently accounts for all volume and mass of water.

### 3.2.1 Terrain and Geometry Data

The acquisition of Lincoln and Adams counties' 2020 surface lidar was facilitated through the utilization of the Washington Department of Natural Resources (DNR) lidar portal. These lidar datasets were then integrated with our bathymetric and topographic survey conducted along Cow Creek, downstream of Sprague Lake, culminating in the creation of a

RAS Mapper Terrain. It is important to note that in densely vegetated areas, the resulting terrain may reflect the tops of bushes and or trees rather than bare earth.

The two-dimensional equivalent of floodplain cross sections is a mesh of grid points. This grid geometry was draped over the terrain with high resolution in the channels, ditches, and overtopping areas. The modeling mesh and associated RAS Mapper Terrain upstream and downstream of the lake are shown below in Exhibits 3-2 and 3-3 below.

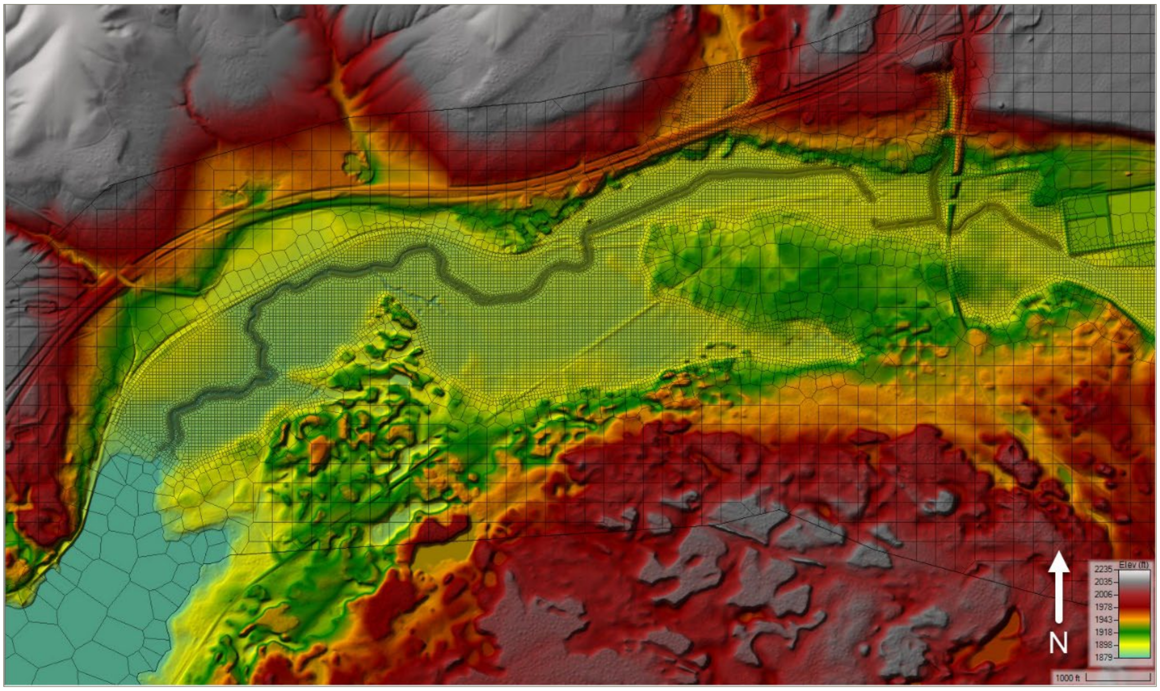


**Exhibit 3-2: Modeling Mesh Upstream of Sprague Lake**

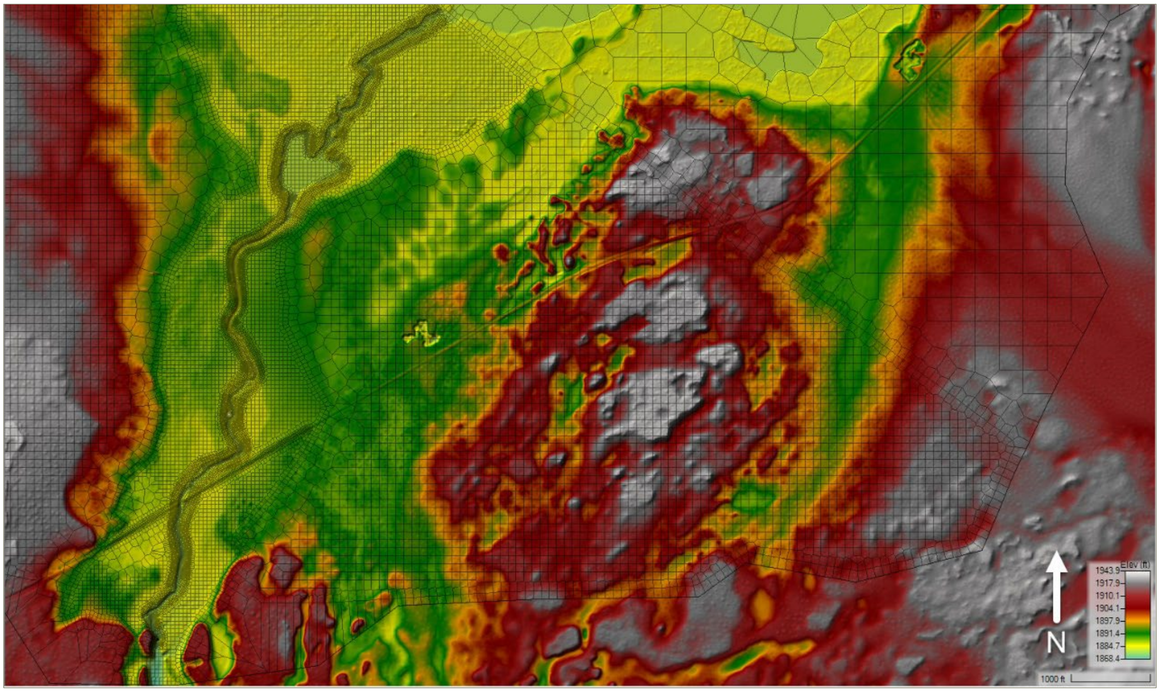


**Exhibit 3-3: Modeling Mesh Downstream of Sprague Lake**

### 3.2.2 Boundary Conditions

The City has expressed concerns regarding conditions that have led to previous flooding of Sprague. As Negro Creek, Sprague Lake, and Cow Creek are all in the FEMA Zone A Floodplain, the permitting/regulatory design storm would be the 100-year event for any infrastructure or fill planned to alleviate floodwater. To address stakeholder flood concerns, specific boundary conditions were established for modeling scenarios. The inflow boundary conditions were set at the approximate outlets of the three contributing drainage basins that feed directly into Sprague Lake (Exhibit 3-4).

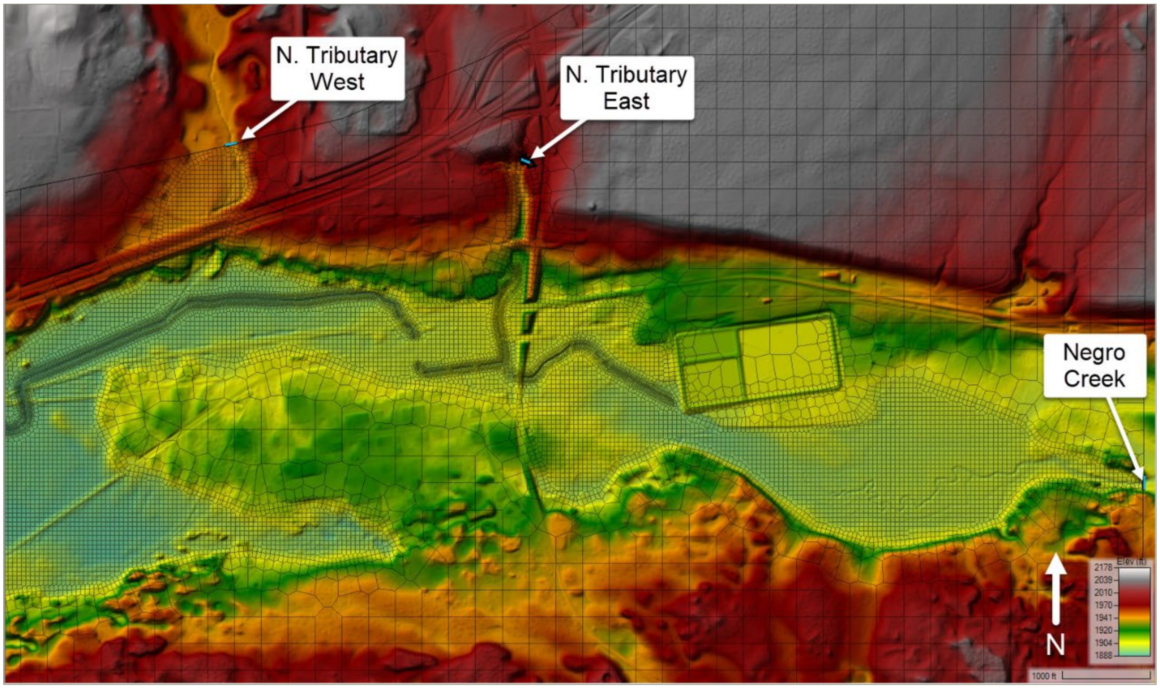


**Exhibit 3-4: Upstream Modeling Boundary Conditions**

In addition, a normal depth downstream boundary condition was added approximately 2 miles downstream of the Sprague Lake outlet. The normal depth was established based on the approximate channel gradient taken from the lidar.

### 3.2.3 Physical Calibration

Sprague Lake is equipped with an Ecology surface gage that has maintained an uninterrupted period of data recording since 2006. The gage not only facilitates the calibration of inflow parameters for the HEC-RAS model, but also enables the assessment of the lake's overall slope. While lakes are generally considered to have a flat surface, this particular system exhibits an elongated shape with a significantly greater length than width. Consequently, with inflows and outflows occurring at opposite ends of its elongated axis, this lake effectively functions as a gently sloping wide river segment.

Water surface data was recorded at the lake outlet throughout a period spanning from February to April 2023. Rainfall measurements obtained from the Fairfield, Washington, rain gauge during the aforementioned period were retrieved, and using HydroCAD, a runoff hydrograph was developed. The resulting hydrograph corresponded to a flood event characterized by a roughly 10-year return period, or a 10% exceedance probability, as ascertained from the StreamStats tool.

However, upon inputting the generated hydrograph into the HEC-RAS model, it became apparent that the resultant lake level exhibited an undesirably rapid and excessive rise, followed by an abrupt decline. This observation contradicted the expected behavior of the system. Subsequent sections of this report elaborate on the underlying reasons for this discrepancy. Specifically, the employed runoff model, tailored specifically for the parameters of this project, failed to accurately capture the hydrological dynamics associated with groundwater and snow melt-driven processes and exaggerated rainfall runoff. Given the nature of the approach adopted for evaluating the site, it is unlikely that developing a more intricate runoff model would significantly alter the findings or recommendations.

Nevertheless, it is crucial to emphasize the value of the logger data acquired during this investigation. These data provided corroboration that the runoff model wasn't properly capturing the hydrology. Furthermore, these logger data can be effectively utilized to compare the disparities in water stage measurements between loggers SW-B, -C, and -D against the disparities exhibited by the HEC-RAS model's water surfaces at each respective location. This comparative analysis was conducted and enabled us to calibrate the hydraulic properties governing water movement within the system. Exhibit 3-5 below provides a visual representation of our stage measurements for loggers SW-B, -C, and -D.

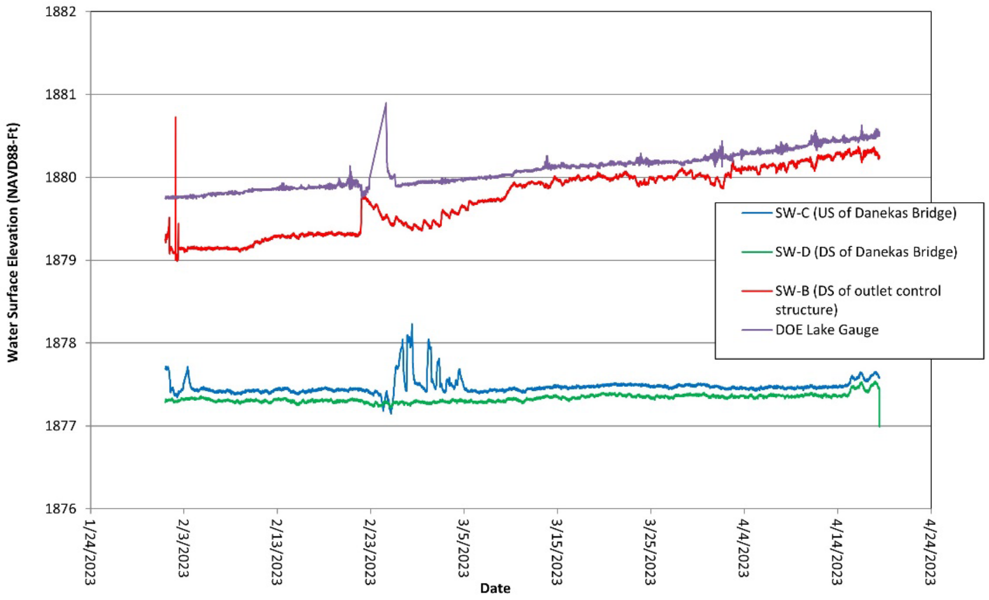


**Exhibit 3-5: Stage Measurements for Shannon & Wilson Logger (February to April 2023)**

### 3.2.4 Ecology Lake Gauge

As the predicted, modeled inflow hydrographs did not match well with logged elevations and were an order of magnitude above what could be expected by adjusting variables in the TR-55 methodology. Shannon & Wilson began to perform a gauge record analysis on the 17 years of data available for the Ecology lake gauge (SPRAD1). Gage data for each year's hydroperiod has a constant rise of lake level through summer, and a constant fall through winter, spring, and summer. Exhibit 3-6 below showcases the lake level trend during the 2016 water year (October 1, 2016, through September 30, 2017), including the maximum lake level for March 2017.

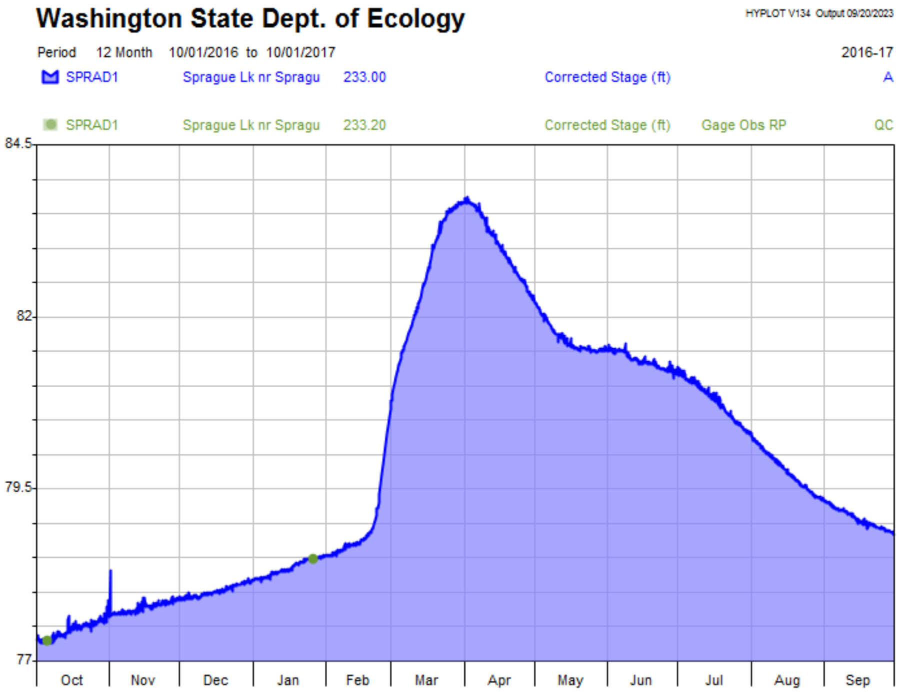


**Exhibit 3-6: Sprague Lake Stage Hydrograph (Water Year 2016)**

Evaluating rainfall data with the Sprague Lake water surface gaged data (shown in Exhibit 3-7 below) indicates that the response to rainfall is muted or attenuated given the high precipitation events mid-winter with nominal associated changes to lake levels.

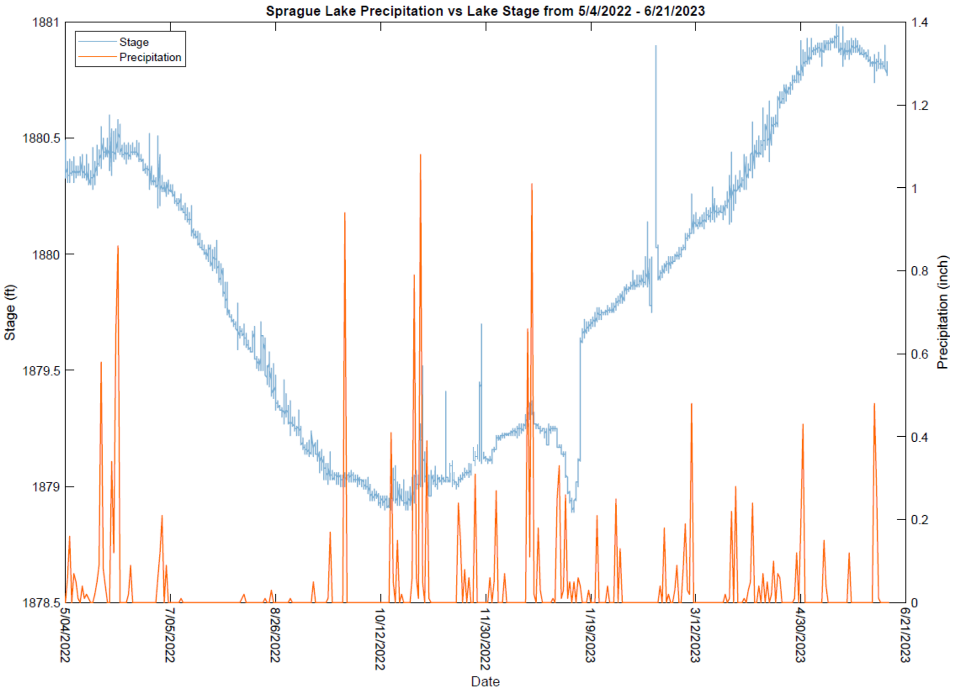


**Exhibit 3-7: Sprague Lake Stage Hydrograph With Rainfall**

Evaluating average daily temperature data with the Sprague Lake water surface gaged data (shown in Exhibit 3-8 below) does indicate a clear signal and response to lake levels related to air temperature. There is a temporal lag between the two data sets, but a clear relationship exists.

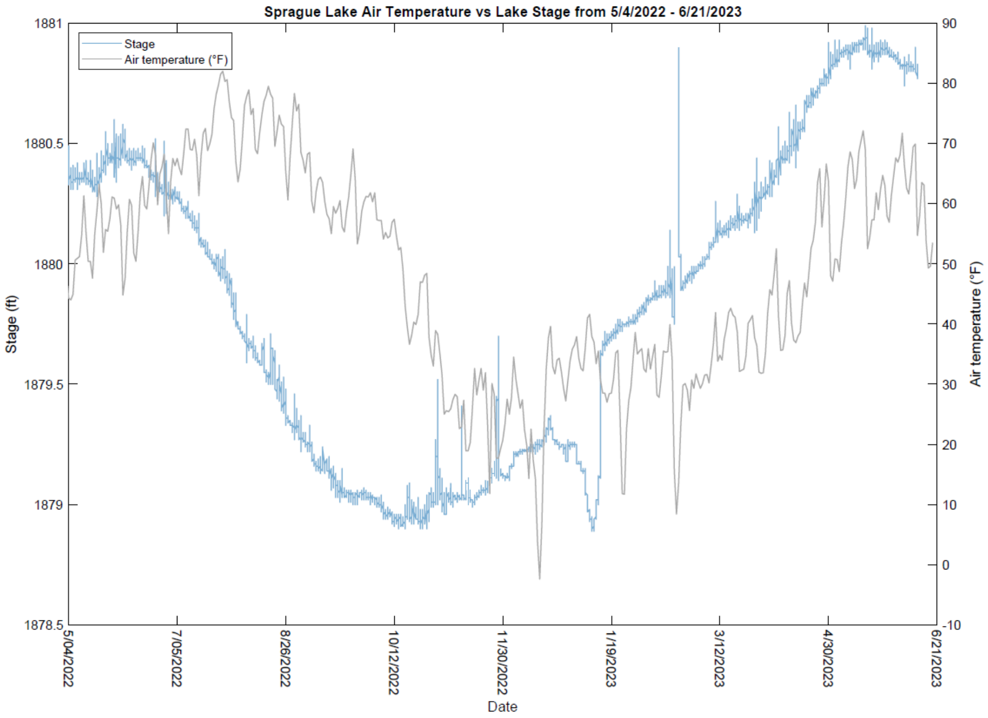


**Exhibit 3-8: Sprague Lake Stage Hydrograph With Average Daily Temperature**

We believe that these factors suggest that upwards of 90% of the rainfall in the Negro Creek basin moves to subsurface flow, and only a small portion remains as surface water. The surface water path to Sprague Lake is significantly faster than the groundwater path, which is drawn out and attenuated with snowmelt.

Accordingly, we can assume from the response in lake level of the Ecology gauge and our loggers for the period of record, that even significant rainfall in the Negro Creek basin does not have a quick enough effect on lake levels to cause a high tailwater on the concrete drainage channel through the City. It is more likely that long periods of multiple high rain events, or spring periods with large snowmelt numbers cause high groundwater and high lake levels. These same conditions are likely to be responsible for Negro Creek flowing at a higher proportion of surface flow than during low groundwater conditions.

The hydrological monitoring of the Sprague Lake drainage basin is currently limited, with no established gauging system in place, apart from the loggers specifically installed for this project. However, the adjacent Crab Creek basin, situated directly to the north of Sprague

Lake, possesses a comprehensive and long-term dataset encompassing both flow rates and water stage measurements. Leveraging the available Crab Creek gauge data served as a viable surrogate to evaluate local runoff characteristics, thereby facilitating the crosswalk of pertinent flood flow events between the adjacent gaged Crab Creek drainage and the ungaged Sprague Lake drainage.

Of particular significance is the 2017 flood event that occurred at Sprague Lake. This event holds merit due to its recency and the availability of corresponding datasets for both Sprague Lake and Crab Creek. Consequently, the 2017 flood event was used as a reference in describing the overall hydrology relevant to this study.

Upon review of the runoff data pertaining to Crab Creek, it is evident that the peak flow observed during the 2017 flood event at the Crab Creek Irby location approximately corresponds to a flood magnitude of a two-year return period, approximately 793 cubic feet per second (cfs), as recorded by the gauge. To provide visual context for this event, a graphical representation depicting the relative magnitude of this 2017 event (red line), in relation to more significant Crab Creek flood events during the 1990s, is presented below in Exhibit 3-9.

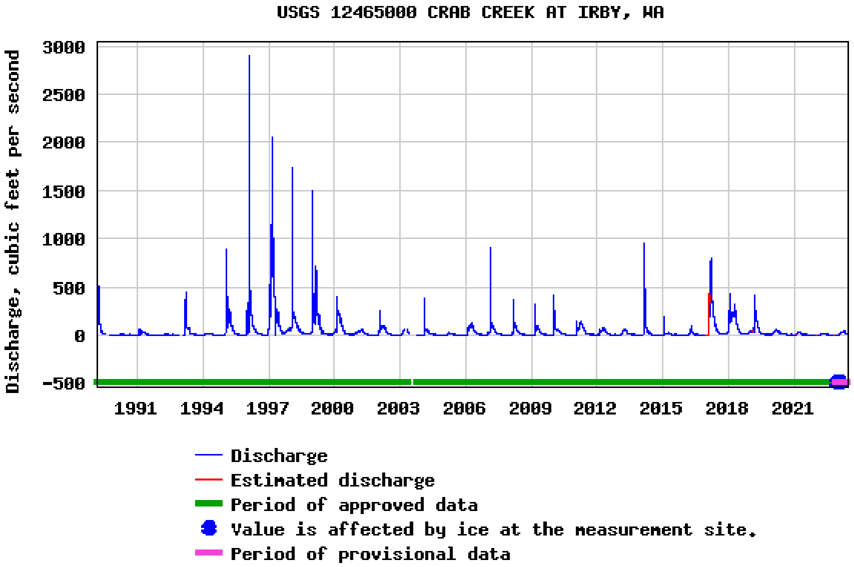


**Exhibit 3-9: Crab Creek Flow Hydrograph (1990 to 2023)**

Further analysis of the 2017 event, as illustrated in the Crab Creek 2016 Water Year graphic below (Exhibit 3-10), reveals a distinctive prolonged tail on the flood hydrograph. This extended duration indicates that the high runoff originating from the basin persisted over an extended period, spanning several months. Notably, this extended duration aligns well with the recorded data from Sprague Lake provided in Exhibit 3-5, suggesting a strong correlation between stream runoff and lake levels, both of which exhibit a dependence on the timing of groundwater and snowmelt driven processes, as opposed to being heavily influenced by intense and short-lived rainfall events.

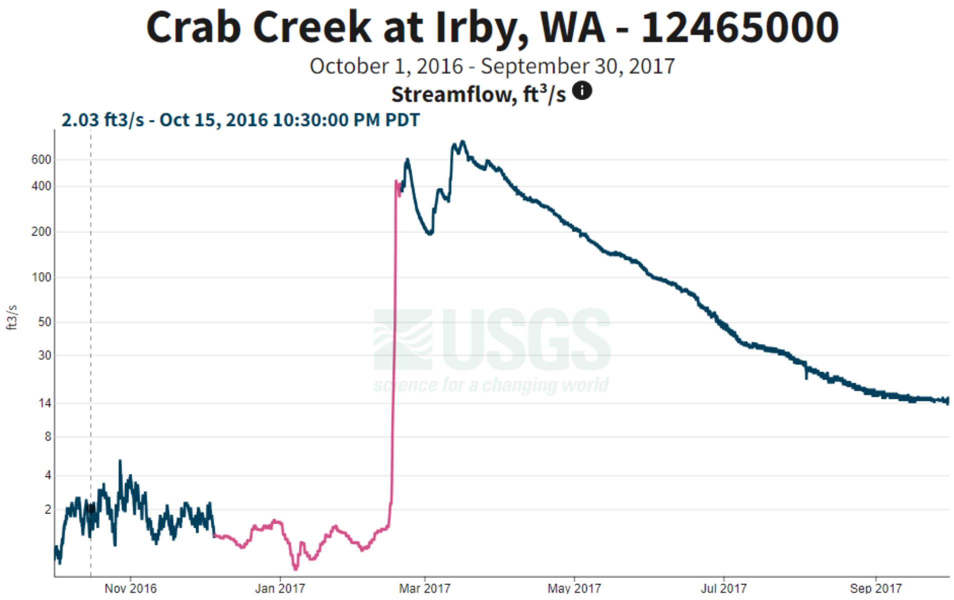


**Exhibit 3-10: Crab Creek Hydrograph (Water Year 2016)**

Due to the availability of gauge data pertaining to both Crab Creek and Sprague Lake during the 2017 flood event, this study focused on analyzing the aforementioned event with regard to two key parameters: lake stage and the inflow of the two-year return period to the tributaries of Sprague Lake.

Furthermore, upon inspection of the Crab Creek data, spanning March and April 2023 (Exhibit 3-11), which coincides with the duration for which data was collected using the loggers installed for the study, it becomes evident that utilizing the HydroCAD data for estimating Sprague Lake runoff leads to a substantial overestimation. As per the StreamStats tool, the projected HydroCAD flow in Negro creek would be the 10-year runoff, which for Crab Creek amounts to 3,380 cfs. However, during this rainfall event timeline, the Crab Creek gauge data exhibited minimal variability in runoff, and the actual recorded peak flow was considerably lower than the anticipated estimate if based on the rainfall event. This observation serves as a clear indication that the hydrology within the basin is primarily driven by the influence of groundwater and snowmelt, rather than by short-term and intense rainfall events.

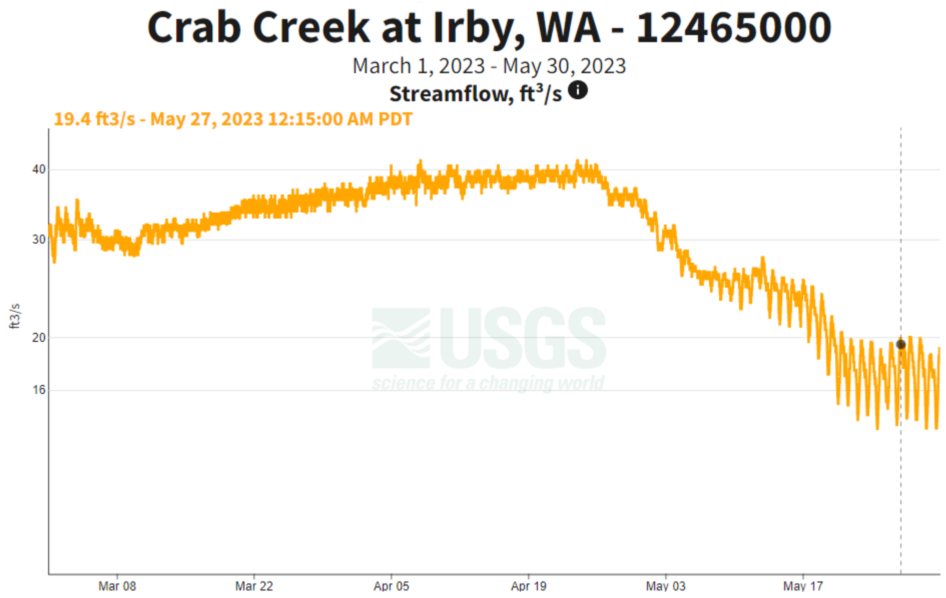


**Exhibit 3-11: Crab Creek Hydrograph (Shannon & Wilson Recorded Period)**

## 3.3 Constriction Analysis

Shannon & Wilson approached the lake outlet constriction analysis from the viewpoint of Sprague Lake at its 2017 peak flood level, as shown in the Ecology gauge. The HEC-RAS model was filled to this level using an empty to full flow rate of 121k cfs to expedite model run times. The lake was then allowed to drain. We ignored effects of inflow for the constriction analysis, as the high lake levels are results of long periods of high groundwater as previously mentioned, and having calibrated the physical response of lake slope and Cow Creek function in our hydraulic model to logger data. Water surface profiles for the constriction analysis can be found in Figures 3 and 4.

### 3.3.1 Channel Bypass / Control Structure

Inspection of the modeling results at the southwest edge of the lake (lake outlet), and from the field observations of the low height of the control structure, suggest that a bypass at the control structure, or removal of the concrete curbs would have little to no effect on the lake levels. The downstream channel of Cow Creek is a significantly tighter constriction than the area of the Control structure. The terrain modifications made to simulate a bypass channel at the control structure are shown in Exhibit 3-12 below.

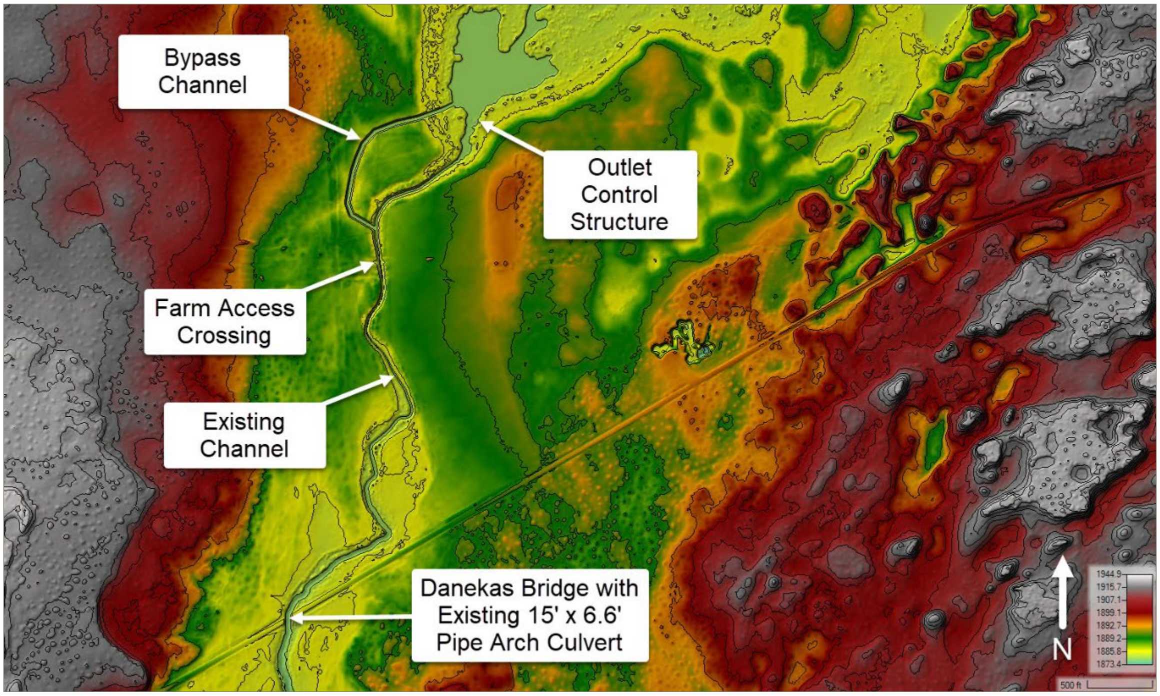


**Exhibit 3-12: Modified Lake Outlet HEC-RAS Terrain (Proposed Bypass Channel)**

## 3.3.2 Channel Dredging

The centerline of Cow Creek does have a high point in the vicinity of the farm access that disrupts the smooth continuity of the creek profile. This high point was removed, and the model was rerun with the 2017-year lake level. Dredging this area or simple cleaning of debris from the channel causes marginally faster draining of the lake, with increased water surfaces (and flow) downstream of the removed high point related to increased lake outflow. The terrain modifications made to represent a dredged channel along Cow Creek are shown in Exhibit 3-13 below.

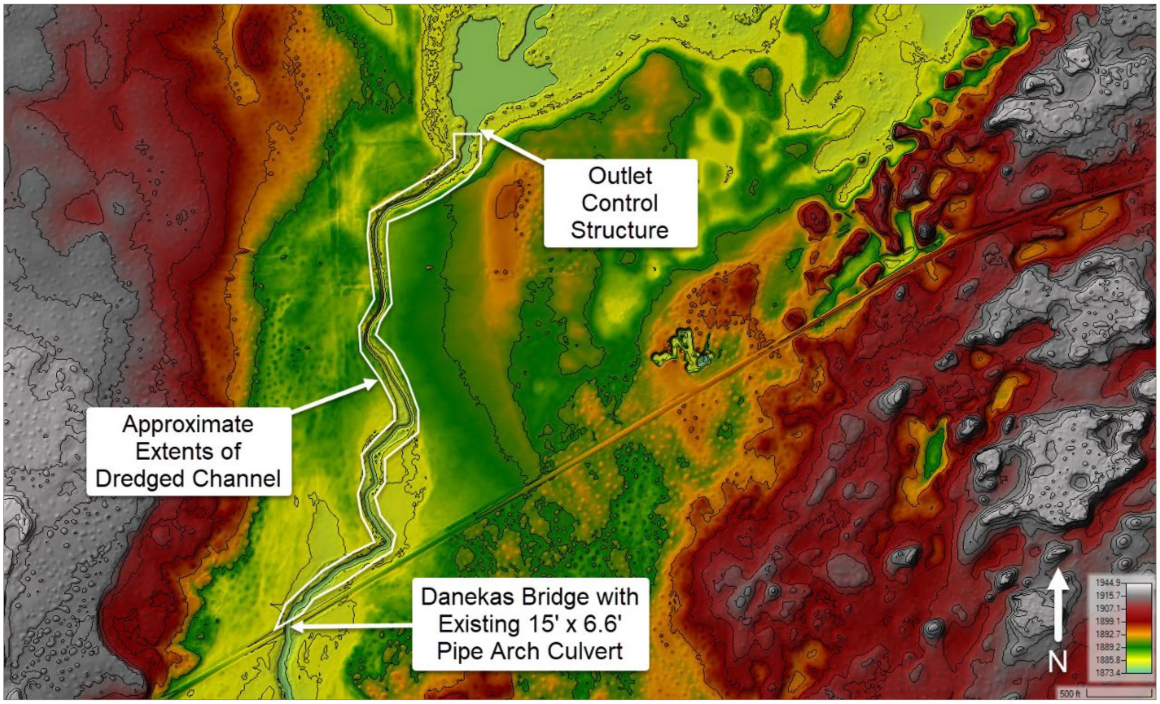


**Exhibit 3-13: Modified Lake Outlet HEC-RAS Terrain (Proposed Dredged Channel)**

### 3.3.3 Channel Widening

The existing channel of Cow Creek is approximately 40 feet wide from bank to bank and has a v-notch shape. In the vicinity of the farm crossing, the channel has a narrower cross section at 25 to 30 feet between banks. The entirety of Cow Creek was recut as a widened 40-foot channel with a rectangular cross section, effectively doubling the available channel area. Although this did result in an improvement in flow capacity and lake elevation, these improvements were on the order of 0.2 foot in reduced lake levels within the lake and an increase from 860 to 1,550 cfs of flow in the outlet channel, which is unlikely to provide functional flood relief for property owners on the shoreline. The terrain modifications made to represent a 40-foot-wide rectangular channel along Cow Creek are shown in Exhibit 3-14 below.

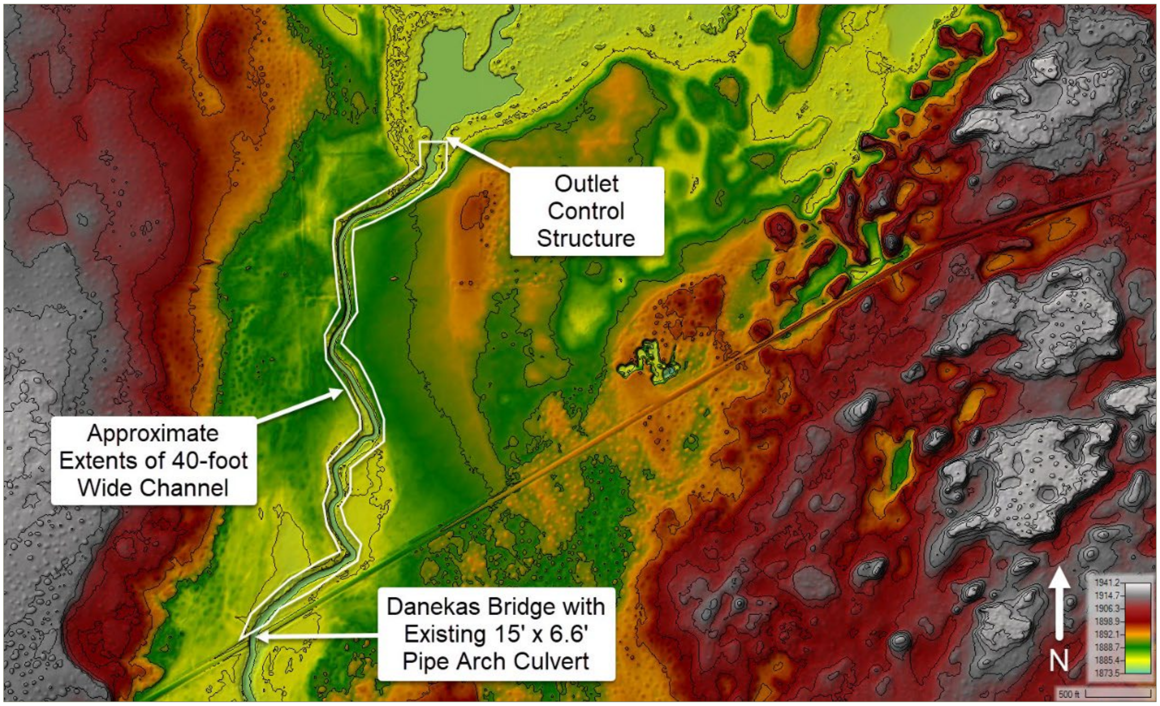


**Exhibit 3-14: Modified Lake Outlet HEC-RAS Terrain (Proposed Widened Channel)**

### 3.3.4 Danekas Road Bridge

The 15- by 6.6-foot pipe arch culvert at Danekas Road is the next constriction point upstream of the rock outcrop. This bridge was widened in the HEC-RAS model to a box culvert 30 feet wide by 7 feet tall (Exhibit 3-15). This widening did provide some improvement in draining of the lake, shortening the estimated time to drain from 25 days (2017 levels) to 23 days. However, as the lake drained at each time step, there was less than a foot of improvement in lake water surface elevation.

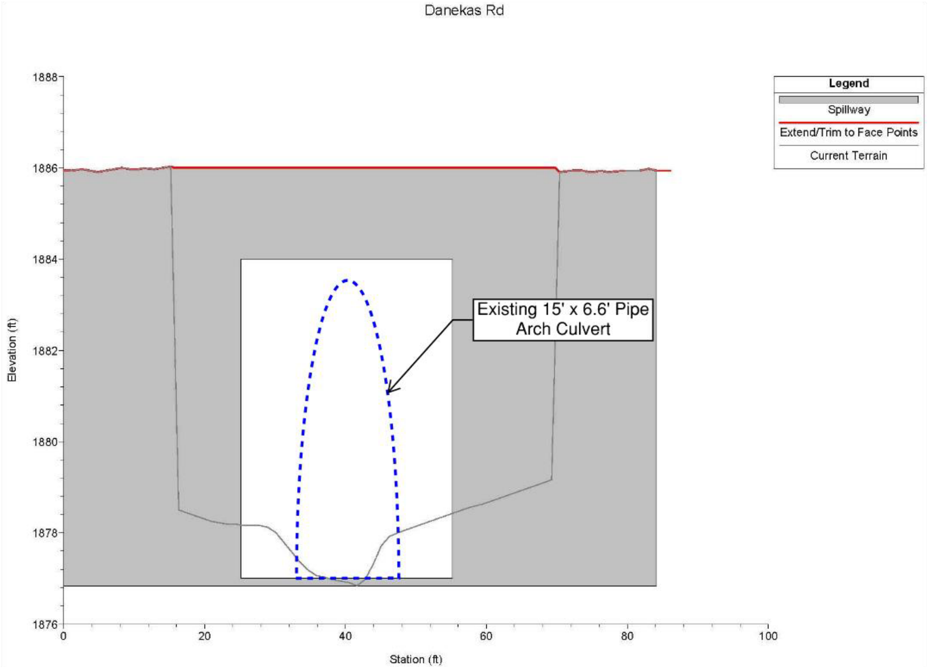


**Exhibit 3-15: Modeled Danekas Road 30- by 7-Foot Box Culvert Schematic**

A detailed study could be performed on how the long duration runoff east of SR 23 influences the flow and flooding in Negro Creek, including assessing improvements to stormwater conveyance through the City, and there are areas where a bypass channel could be constructed south of the existing concrete drainage structures. However, the bypass would likely come at extreme cost of earthwork and engineering, and analysis of a bypass and stormwater improvements are not part of the scope of this study.

## 3.4 Sensitivity Analysis – Large Scale Alternatives

As part of a sensitivity analysis, we have undertaken the development and execution of three additional larger scale outlet modification alternatives. To ensure the bedrock constriction downstream of Danekas Bridge did not influence the results, we extended our modeling grid in a southerly direction, effectively incorporating the rock outcrop as shown in Figure 2 and depicted in Exhibit 3-16 below. Modifications to the bedrock outcrop were not considered, but would not be expected to change the findings relative to flood lake levels. The ensuing sections provide detailed descriptions of the three large scale alternatives evaluated.

1. *Existing Conditions Model*: This model serves as the reference point, encapsulating the hydraulic dynamics under existing conditions.
2. *Alternative Model 1 – 80-Foot-Wide Channel*: The introduction of an 80-foot-wide channel, extending from the control structure to a location approximately 200 feet downstream of Danekas Bridge.

3. *Alternative Model 2 – Bypass Channel to Danekas Bridge*: The introduction of a bypass channel originating from the control structure and extending to Dankas Bridge with the inclusion of the previously proposed 30- by 7-foot box culvert as depicted in Exhibit 3-15.

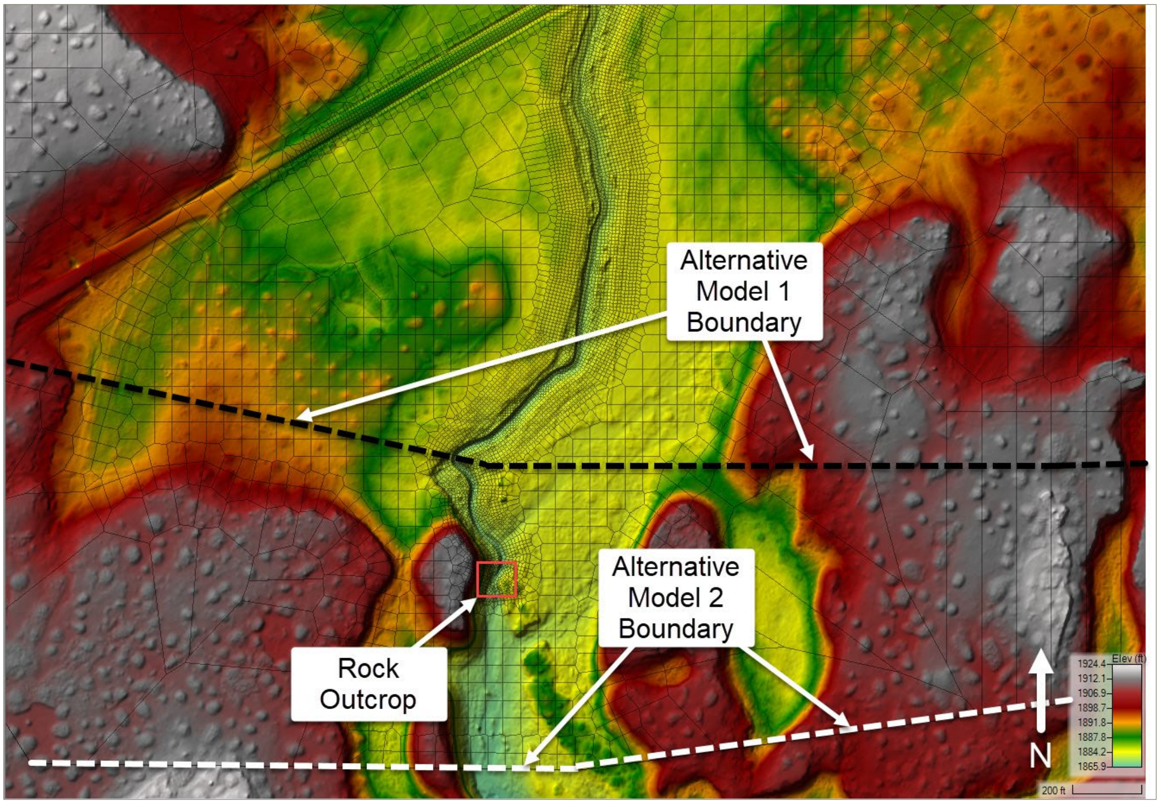


**Exhibit 3-16: Large Scale Alternative Modeling Extents With Inclusion of Rock Outcrop**

## 3.5 Large Scale Alternative 1 – 80-Foot-Wide Channel

For the first of two large scale alternatives, Cow Creek was recut as a widened 80-foot channel with a rectangular cross section. This channel excavation extended from the outlet control structure, reaching a point approximately 200 feet downstream of Danekas Road. The outcome of our modeling analysis revealed a reduction in peak lake levels, amounting to an approximate decrease of 0.2 foot at the peak. Furthermore, the post-peak lake levels indicated a reduction in lake levels of approximately 2.8 feet when considering a four-day drainage period after the peak levels.

Moreover, these alterations yielded a change in peak flow capacity within the Cow Creek channel, increasing from 860 to 2,900 cfs. It is worth noting that, similar to the proposed 40-foot wide channel alternative, this configuration is not deemed conducive to providing effective flood mitigation for landowners situated along the northeast shoreline of Sprague

Lake. A representation of the topographical modifications for the 80-foot-wide rectangular channel are provided in Exhibit 3-17 below.

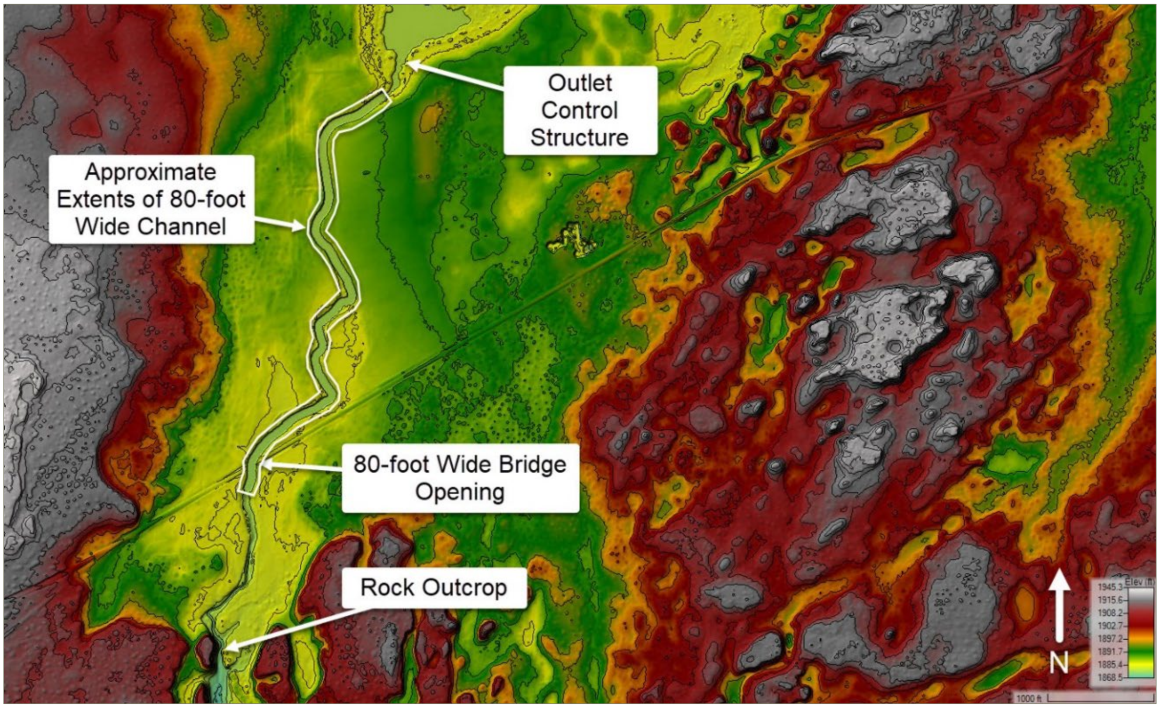


**Exhibit 3-17: Modified Lake Outlet HEC-RAS Terrain (Proposed Large Scale Widened Channel)**

## 3.6 Large Scale Alternative 2 – Bypass Channel to Danekas Bridge

For the second large scale alternative, a bypass channel was excavated, extending from the outlet control structure to a location immediately upstream of Danekas Road, situated to the west of Cow Creek. Additionally, the inclusion of a 30- by 7-foot box culvert along Danekas Road was proposed to facilitate enhanced drainage and conveyance efficiency within the system. A detailed representation of the topographical modifications required are provided in Exhibit 3-18 below.

Based on the modeling analysis, the peak lake levels exhibited a reduction of 0.1 foot compared to the existing conditions. Following a four-day drainage period, the lake levels demonstrated a decrease of approximately 1.5 feet when compared to existing conditions.

Moreover, the peak flow rates in Cow Creek experienced an increase in flow through Danekas Road from 860 to 1500 cfs.

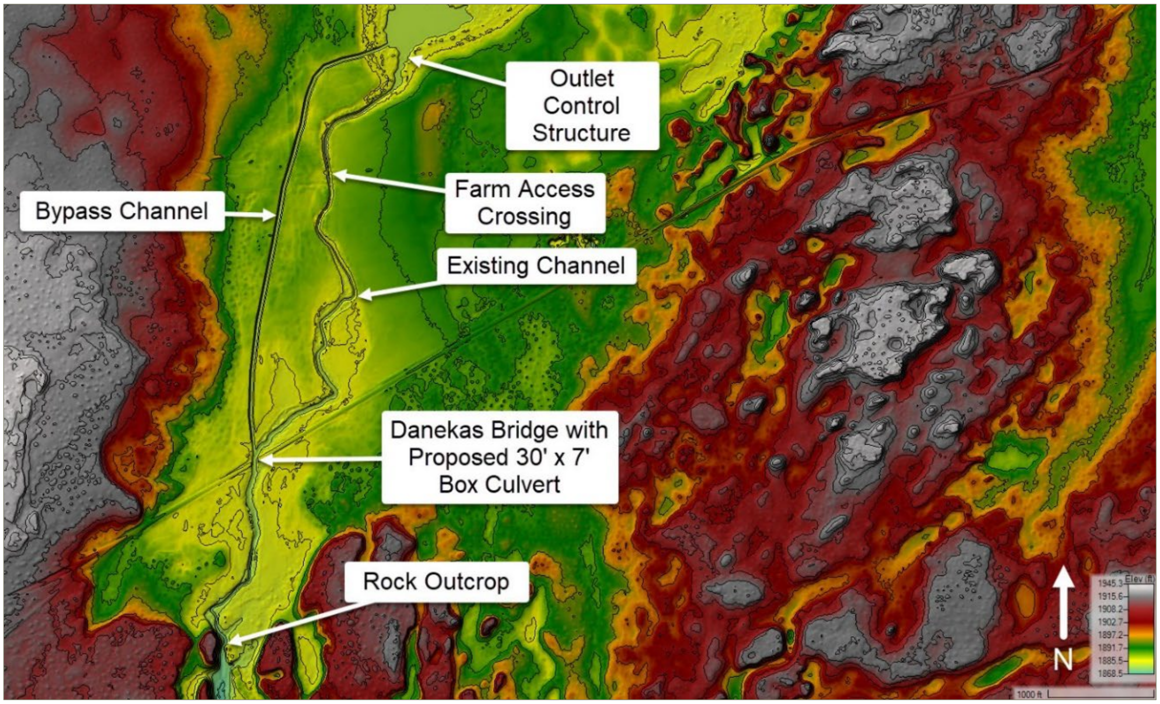


**Exhibit 3-18: Modified Lake Outlet HEC-RAS Terrain (Large Scale Proposed Bypass Channel)**

## 3.7 Flooding – City of Sprague

While it is outside the scope of this study to accurately predict surface water flows into the City, the infrastructure in the City has a consistent flow rate at which box culverts and concrete channels are overwhelmed and begin to flood. Looking at our representative hydrograph, which includes a rise and fall of flow, this overwhelming point occurs upstream in the system at roughly 370 cfs, and in the downstream of the system at roughly 450 cfs.

The relationship between City flooding, lake levels, and whether flooding is a symptom of overwhelmed culverts and drainage systems during high flow events was further evaluated. We ran a two-year, 654 cfs steady state flow through Negro Creek, 24.9 cfs North Tributary East, and 192 cfs North Tributary West into the City with a lake level held at the April 2023 logger lake level and at the extreme maximum 2017 lake level. This two-year simulation floods roughly 10 square blocks of the City in both the high lake level condition and the low lake level condition. The water surface profile provided (Figure 5) indicates that the upstream backwater effect from the two-year flood event with the 2017 maximum lake water surface versus the "lower" lake water surface from our logging interval is near the private road crossing, about 5,000 feet upstream of the lake. It is reasonable to conclude that flooding in the City is not from tailwater effects of the lake but likely from overwhelmed drainage systems within the City.

# 4 WAVE ANALYSIS

Sprague Lake is susceptible to wind-induced wave activity. To evaluate the potential impact of these waves on upstream flooding in the City, Shannon & Wilson employed methodologies outlined in the USACE Coastal Engineering Manual (2015) to compute wave parameters of relevance. The primary parameters of interest encompass wave height, wave period, and breaking wave height. By comparing these parameters with the hydraulically modeled flooding resulting from surface flow inputs, the analysis aims to discern the dominant factor contributing to problematic flood events.

In this assessment, wave runup (Exhibit 4-1) was excluded from consideration, given that the area under investigation for a wave runup analysis requires a steep embankment or shoreline. Specifically, the northeast shore of Sprague Lake, where Negro Creek converges with the lake, exhibits a gradient of less the 5%, indicating a shallow slope. Additionally, boat-generated waves were not factored into the analysis. While Sprague Lake hosts an active boating community, the vessels employed for recreational purposes are relatively small and unlikely to generate waves of sufficient magnitude to contribute to flooding extents.

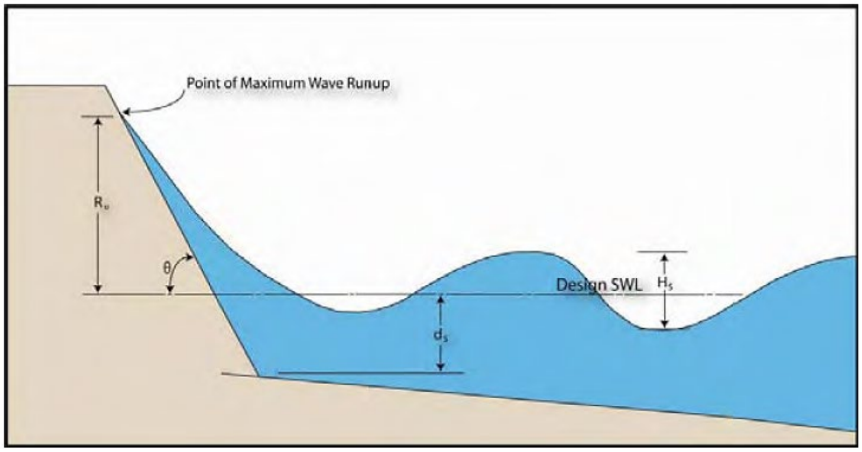
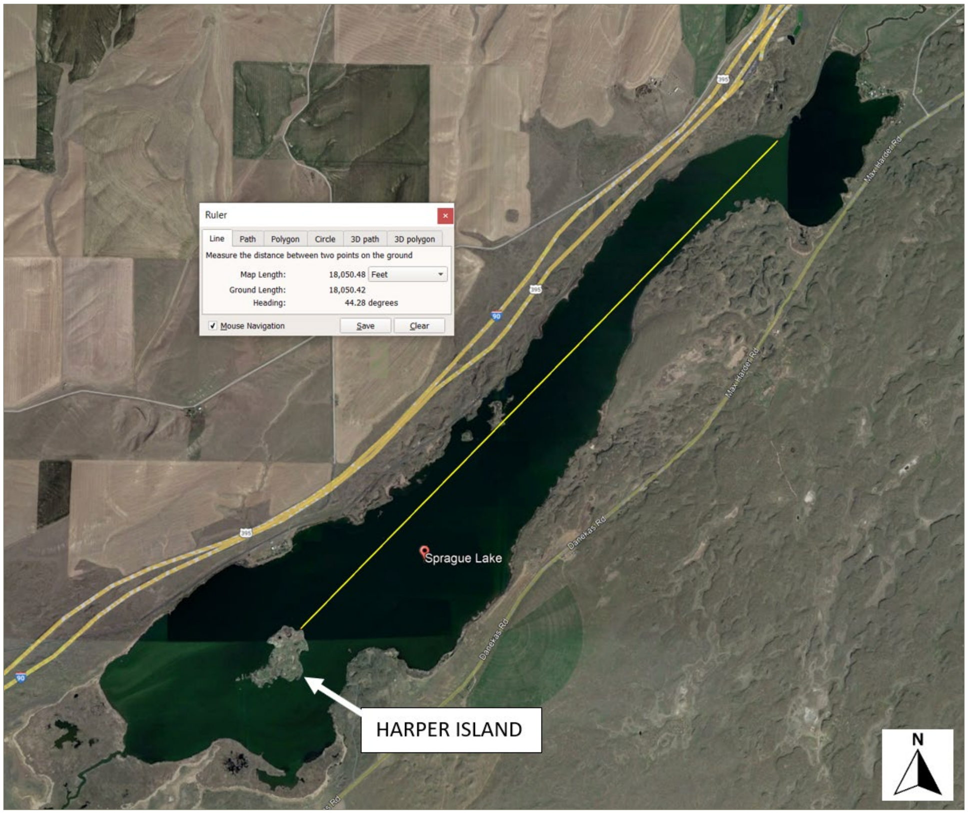


**Exhibit 4-1: Wave Runup on a Steep Embankment (Figure 6.17 From the Federal Highway Administration's Hydraulic Engineering Circular No. 25 [Douglass, 2020])**

## 4.1 Wind Waves

In accordance with the USACE Coastal Engineering Manual (CEM), we have determined the design wind and wave parameters by considering the specific site fetch and corresponding design wind speed and orientation. The fetch in the area of interest is influenced by Harper Island (Exhibit 4-2), situated near the southwest (outlet) end of the lake, as well as the curved shoreline at the northeast end (inlet). The calculated fetch length extends approximately 18,050 feet towards the northeast.



Measure the distance between two points on the ground

Map Length: 18,050.48 Feet
Ground Length: 18,050.42
Heading: 44.28 degrees
☑ Mouse Navigation

**Exhibit 4-2: Fetch Measurement (Google Earth)**

To establish the design wind speeds, we reference the American Society of Civil Engineers (ASCE) Standard 7-16 (ASCE, 2017). This standard offers estimates of three-second wind gust speeds for various recurrence intervals based on location. The estimated 1% Annual Exceedance Probability (AEP) three-second wind speed at the project location is determined to be 87 miles per hour (mph). However, it is important to note that a three-second wind gust does not generate a significant wave set. To fully generate fetch-limited waves for the given fetch length of 18,050 feet, a sustained wind duration of 15 minutes is necessary (EM-1110-2-110 P2, II-2-4 of the CEM).

The CEM provides an equation for converting wind speeds of one duration to an AEP-equivalent wind speed of a different duration. Utilizing this equation, we derive a 15-minute design wind speed of 60 mph. The resulting wave parameters are summarized in Exhibit 4-3 below.

**Exhibit 4-3: Design Wave Parameters**

| Wave Height (feet) | Wave Period (seconds) | Break Wave Height (feet) |
|---|---|---|
| 3.9 | 2.7 | 3.4 |

In addition, we reviewed the wind and lake level time series for the period of logger data; it can be seen that for the duration of the logger data, winds from the southwest (northeast direction) have very little impact (on the order of a few tenths of a foot) on lake water surface elevations at the Ecology Gage to the northeast (Exhibit 4-4).

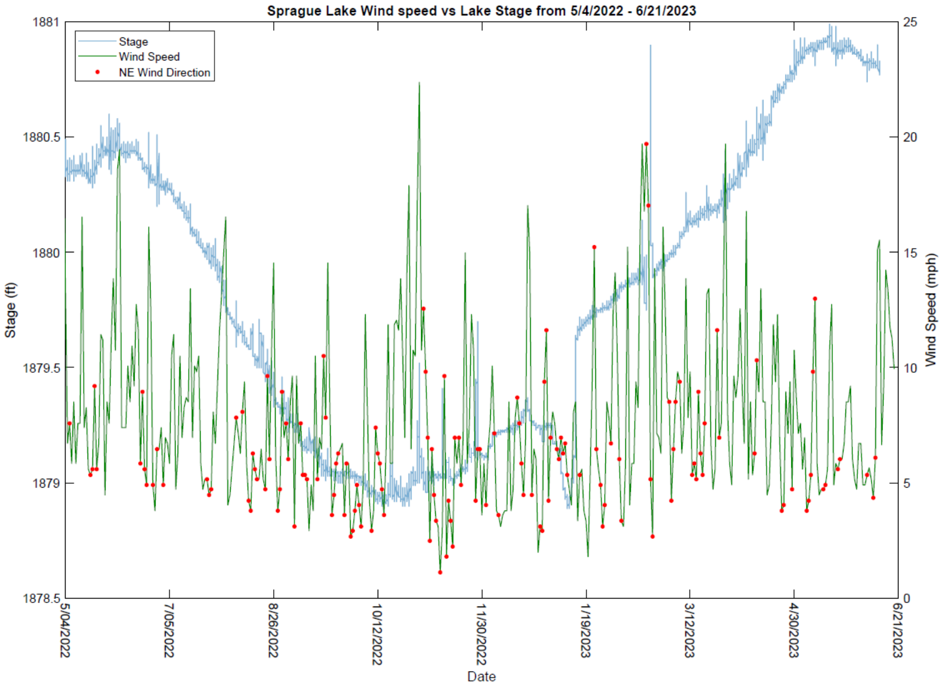


**Exhibit 4-4: Correlation Between Lake Stage, Wind Speed, and Precipitation**

## 4.2 Summary of Wave Analysis

The minimum elevation of structures within the City is estimated to be approximately 1,895 feet. During the peak months of April through June, the approximate elevation of the lake water surface reaches 1,880 feet. Considering a calculated wave height with a recurrence interval of 100 years, measuring 3.9 feet, it follows that the most vulnerable homes in the City would be situated approximately 11.1 feet above the wave height. Consequently, it is rational to assert that wave-induced flooding does not pose a threat to the City's infrastructure, but rather the Lakeside residents and the campground are likely the most impacted by waves.

# 5 SUMMARY OF PERMITTING REQUIREMENTS

Excavation of larger or new channels at the lake outlet would require extensive permitting. The permitting challenges are related to direct and indirect permanent and temporary impacts to lake, stream, wetlands, and/or buffers within the construction areas of the alternatives. The nature and extent of the direct impacts will depend on the design of selected alternative(s). The project would also likely lower the "low lake" water surface, with resulting indirect impacts to the wetlands (both area and conditions) and hydrology around the lake. These direct and indirect effects would require potentially substantial compensatory mitigation and may prove infeasible to permit if alternative flood risk reduction options exist. Based on the conceptual alternatives evaluated in this report, we have provided a list of likely permits and environmental reviews that would be required.

1. State Environmental Policy Act (SEPA): The project would require compliance with SEPA, and we assume that Ecology would act as the SEPA lead agency. A SEPA Checklist would be prepared first, potentially followed by an Environmental Impact Statement (EIS) if the Checklist review concludes with a Determination of Significance. Preparation of an EIS is a costly and time-consuming process. If federal funding is used or other federal nexus triggered, National Environmental Policy Act (NEPA) approval would also be required, which would likely further increase both cost and schedule of permitting.
2. County Shoreline Permit(s): Sprague Lake is a Shoreline of Statewide Significance and Cow Creek is a Shoreline of the State. Shoreline waterbodies are subject to the Shoreline Master Programs of Lincoln (creek only) and Adams counties (creek and lake). Dredging for flood management purposes in the aquatic environment may be allowed with a Substantial Development Permit, but other improvements or modifications in or adjacent to the water may require a Conditional Use Permit (CUP). Further, because Sprague Lake is a Shoreline of Statewide Significance, any project in or affecting the lake has to demonstrate consistency with a set of use preferences that emphasize statewide over local interests, preservation of the natural environment, and other criteria that may be difficult for a project of this type and in this setting. Depending on the design of the chosen alternatives and their location with respect to other critical areas, a Shoreline Variance may also be required. CUPs and Variances also have specific criteria that must be met and can be challenging and time-consuming to obtain.
3. WDFW Habitat Project Approval (HPA): Projects in lakes or streams that "use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state" (RCW 77.55.011(11)) will require an HPA.
4. USACE Section 404 Clean Water Act (CWA) Authorization: Per Section 404 of the CWA, a review process is required for projects involving discharges of dredge or fill materials into jurisdictional waters of the United States. Any proposed impact located within a jurisdictional wetland or stream would require either a Nationwide Permit (NWP) or an

Individual Permit from USACE. The potential projects being considered are unlikely to qualify for a NWP, so an Individual Permit would be required. Individual Permits require preparation of an Alternatives Analysis that shows that the proposed project is the Least Environmentally Damaging Practicable Alternative (LEDPA). USACE can only authorize the LEDPA. Projects that require or trigger a federal permit from USACE would also require approval under the Endangered Species Act (addressing yellow-billed cuckoo and monarch butterfly), Magnuson-Stevens Fishery Conservation and Management Act (addressing designated Chinook salmon essential fish habitat), and Section 106 of the National Historic Preservation Act (addressing effects on historic properties).

5. Ecology Section 401 CWA Individual Water Quality Certification (WQC): Ecology has been authorized to implement Section 401 of the CWA for WQC in Washington for most projects that require USACE permits under CWA Section 404. Typically, projects requiring a USACE Individual Permit also require an Individual WQC. The purpose of the certification process is to ensure that federally permitted activities comply with the federal CWA, state water quality laws, and any other applicable state laws. Some general requirements for Section 401, if it is required, include pollution spill prevention and response measures, disposal of excavated or dredged material in upland areas, use of fill material that does not compromise water quality, clear identification of construction boundaries, and provision for site access to the permitting agency for inspection. The project would require preparation and implementation of a formal Water Quality Monitoring and Protection Plan.
6. DNR: Once the project has been defined, DNR should be contacted to discuss whether any of the project falls into aquatic lands under their jurisdiction and to determine whether a right-of-entry or aquatic lands lease needs to be obtained. This process can be lengthy.
7. The alternatives studied fall within Adams County and are mapped FEMA Zone A. Zone A is a flood hazard area that has been mapped using approximate methods with no detailed studies (hydraulic modeling) or Base Flood Elevations being developed. Changes to the outlet by design would result in increased flows and would need to be modeled (potentially far downstream) and likely result in a re-mapping of the FEMA flood zone (CLOMR/LOMR) depending on the findings from the detailed modeling study and alternative considered. Regardless of FEMA requirements, a downstream flood risk study to understand risk to downstream stakeholders would be required.
8. Other local and state land use and environmental permits may also be required.

Special critical areas studies, including delineation of wetland boundaries, ordinary high water mark, and documentation of fish and wildlife habitat along with preparation of other technical reports will be necessary to support project design and permitting.

Depending on which alternative or combination of alternatives is chosen and the nature and extent of impacts, the planning level cost for permitting alone could range between $200k to $500k. Flood risk modeling would likely be between $100k to $300k, depending on the extent and remapping required. This cost does not include compensatory mitigation. Developing an appropriate mitigation strategy would be heavily dependent on the proposed design, further analysis of direct and indirect impacts to aquatic habitats and buffers, and may be subject to extensive negotiations with resource agencies and local tribes. Depending upon the type and extent of mitigation, additional property acquisition or easements may be required. Finally, downstream flood risk mitigation costs may be extensive. Environmental mitigation costs would likely far exceed the permitting costs if the low water elevation of the lake is lowered, likely resulting in extensive wetland impacts around the lake and not just at the project site.

# 6 CONCLUSIONS AND RECOMMENDATIONS

It is our opinion that outlet improvements explored for this study have low flood risk reduction value for City residents and likely marginal value to lakeside residences. The long duration hydrology and influence of groundwater and snowmelt on the runoff hydrographs and lake levels would likely require a major reconfiguration of the lake outlet with nominal improvements in flood risk reduction to residences surrounding the lake. Improving conveyance at the outlet would likely lower the dry season low water lake surface elevations and provide nominal relief from wind and wave damage; however, it would likely not significantly improve wet season lake levels when wind damage is most likely to occur. Additionally, lowering dry season lake levels would impact lakeside wetlands and may impact downstream water rights. This study looked at a broad range of outlet conveyance improvements to understand the lake outlet hydraulics; however, the alternatives evaluated were bounded by scope, budget, and what would be anticipated as reasonable modifications. Alternatives, such as improving local drainage infrastructure within the City and a detailed study of lakeside residential flooding was not conducted. Home elevations, property acquisition from willing sellers, and major civil works were not included in the study.

To better evaluate City flooding, we recommend installation of water level loggers (gages) upstream of the City and potentially within the City drainage network to better understand flooding and provide valuable data for future design and infrastructure improvements.

If more detailed understanding of lakeside residence flooding is needed, we would recommend a more detailed hydrologic study of the lake hydrology to better understand potential improvements to the outlet and their specific risk reduction impacts to lakeside individuals, both in duration and likelihood of flooding, with an associated alternatives and cost benefit analysis. In addition, long-term gage installation (7 to 10 years) upstream of the lake and downstream of the lake would further add detail and understanding to the lake hydrology and is recommended if further analysis is anticipated.

# 7 LIMITATIONS

This report was prepared for the exclusive use of Ecology and their representatives for specific application to the project. Our judgements, conclusions, and interpretations presented in the report should not be construed as a warranty of existing site conditions, nor future estimated conditions. It is in no way guaranteed that any regulatory agency will reach the same conclusions as Shannon & Wilson. Our assessment, conclusions, and recommendations are based on the limitation of our approved scope, schedule, and budget described in our contract.

Key limitations associated with this assessment include:

- Hydrologic and hydraulic analysis models predict flood water surface elevations based on limited data and numerical modeling techniques. Actual flood conditions may vary from the model predicted conditions.
- Rivers and floodplains are dynamic systems and will change compared to the modeled condition.
- The hydraulic model does not consider changes in future conditions due to changes in land use conditions, river and floodplain conditions, structure conditions, or climate change.

Site conditions may change due to natural forces or human activity under, at, or adjacent to the site. If changes occur, we should be retained to review the applicability of our conclusions and recommendations.

Shannon & Wilson has included a document, “Important Information About Your Geotechnical/Environmental Report,” to assist you and others in understanding the use and limitations of this report.

# 8 REFERENCES

American Society of Civil Engineers, 2017, Minimum design loads and associated criteria for buildings and other structures: Reston, Va., American Society of Civil Engineers, ASCE Standard ASCE/SEI 7-16, 2 v.

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SHANNON & WILSON

Sprague Lake Hydrology Analysis
WA State Department of Ecology
Sprague, WA

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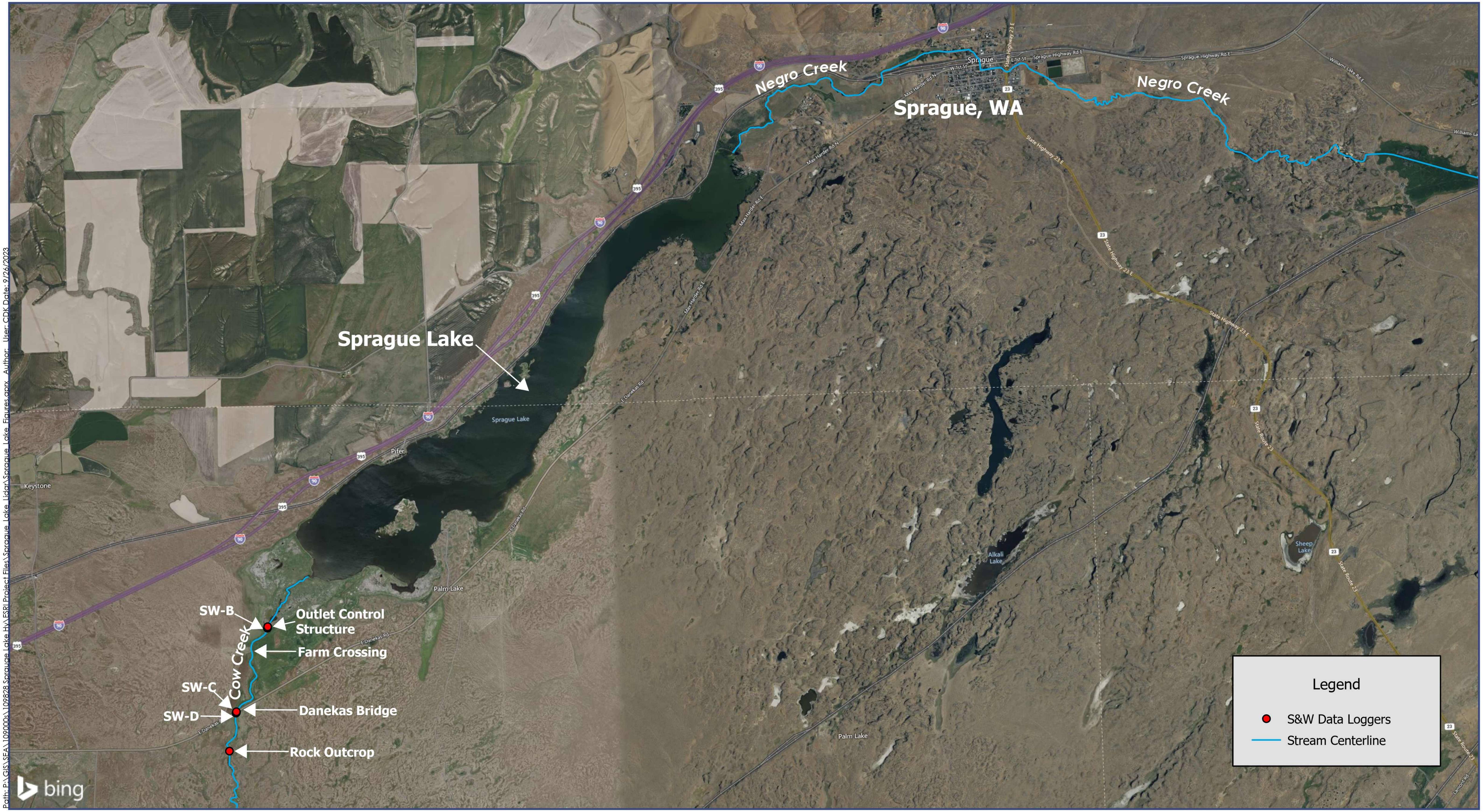
October 2023

**VICINITY MAP**

**Figure 1**



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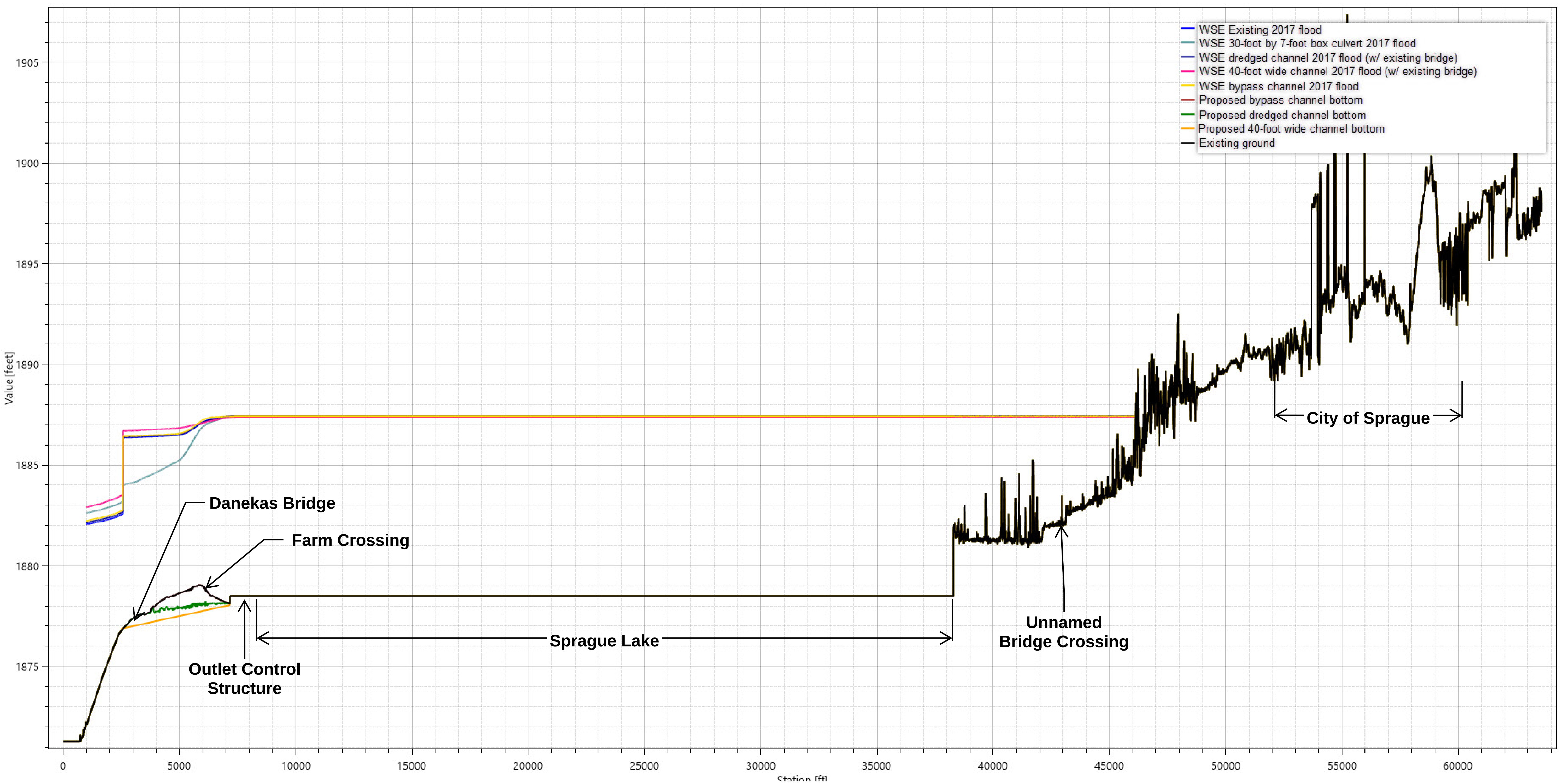
**SITE PLAN**

**Figure 2**



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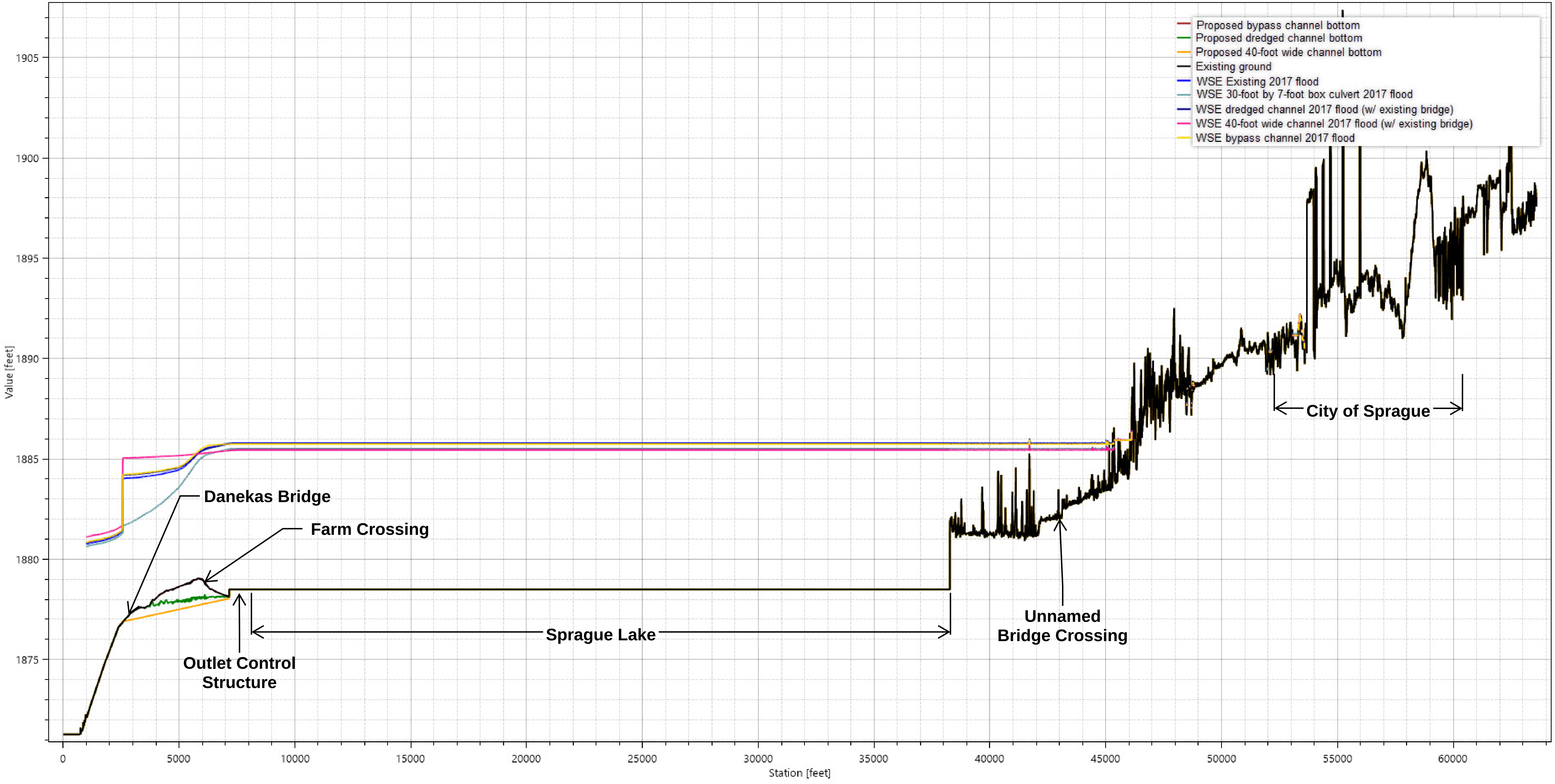
October 2023

2017 Flood Profile - Peak Water Surface Elevations

Figure 3



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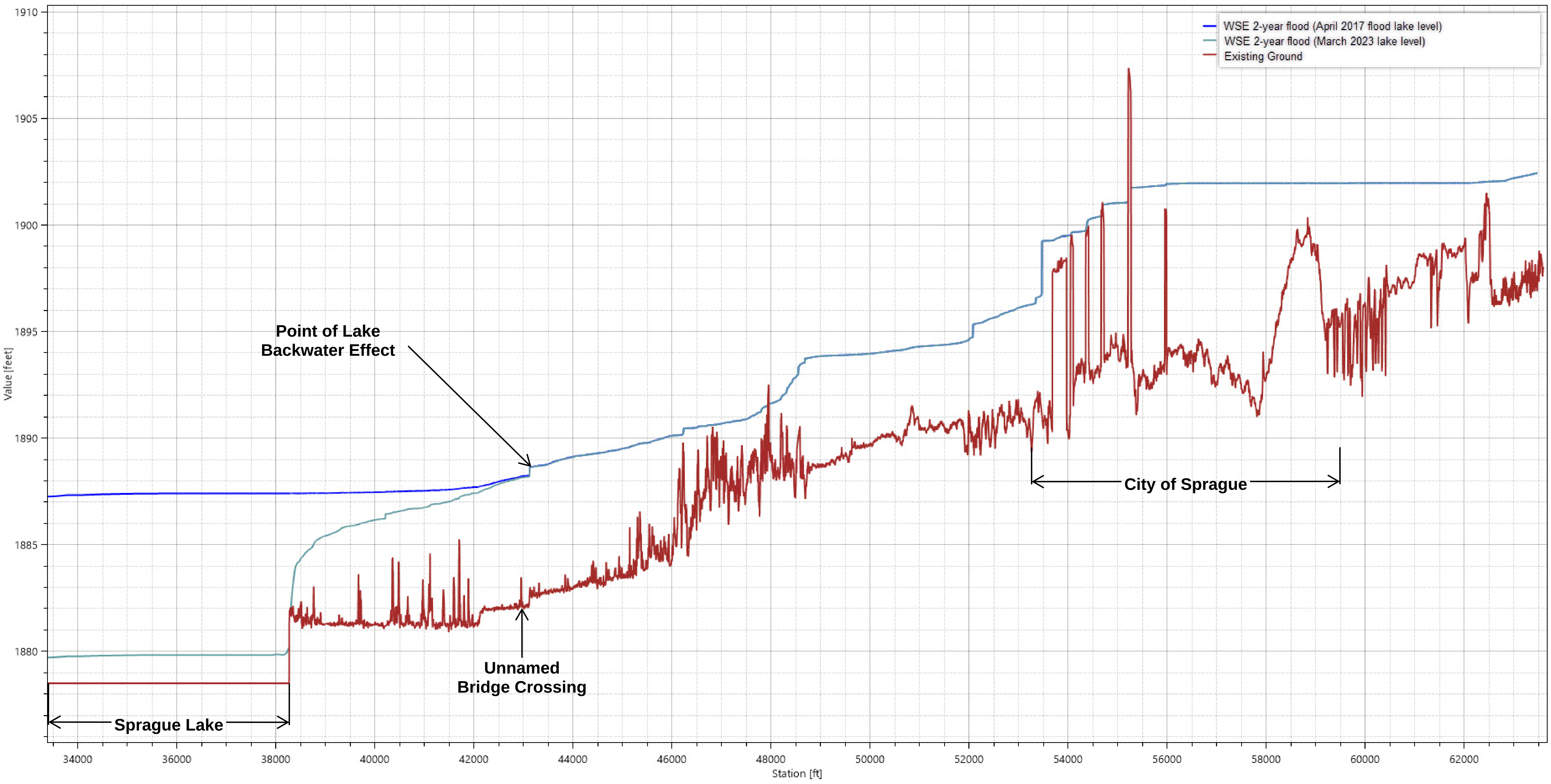
October 2023

**2017 Flood Profile - 4 Days Following Peak Water Surface Elevations**

**Figure 4**



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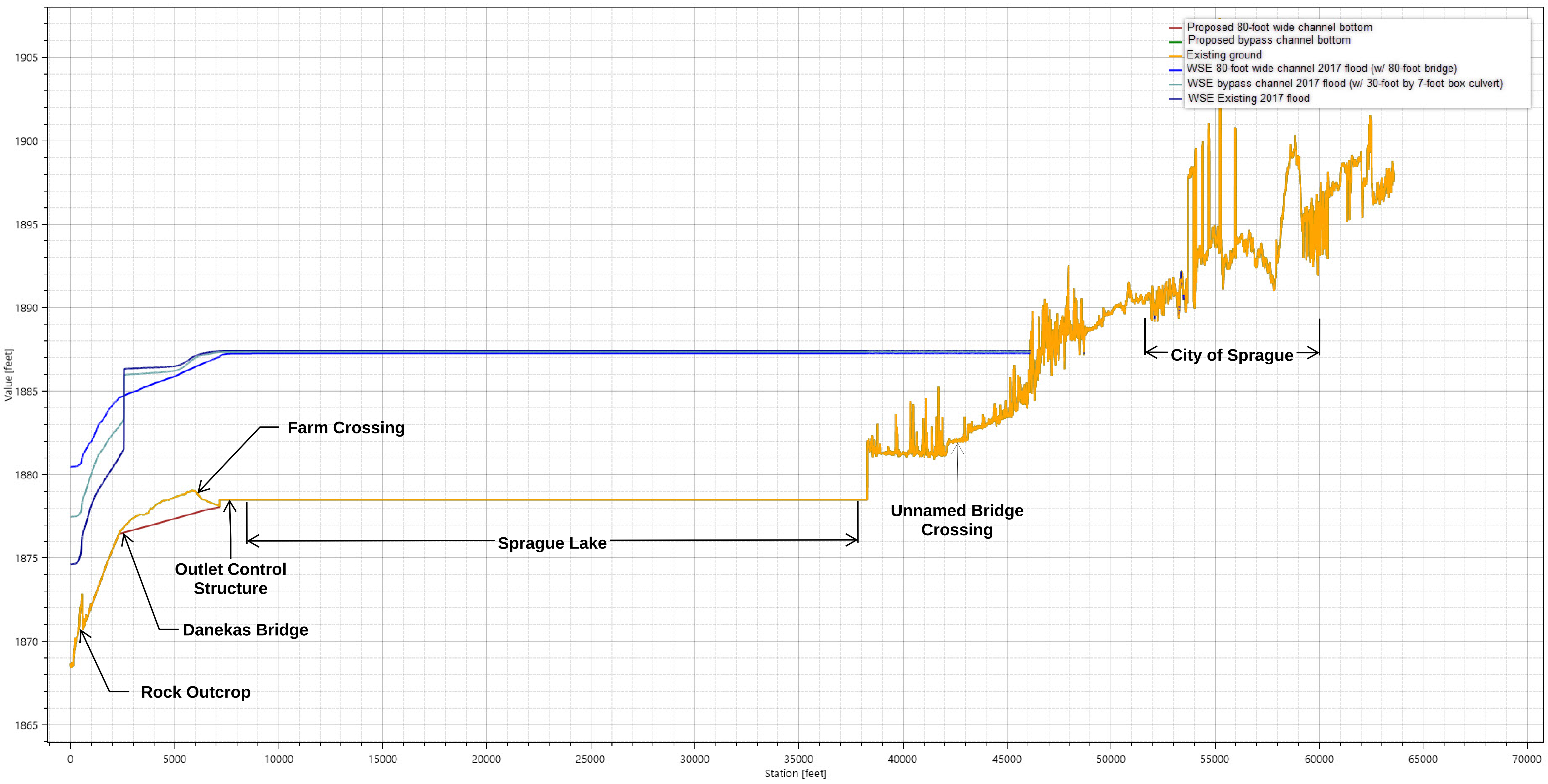
October 2023

2-Year Flood Profile - **City** of Sprague

Figure 5



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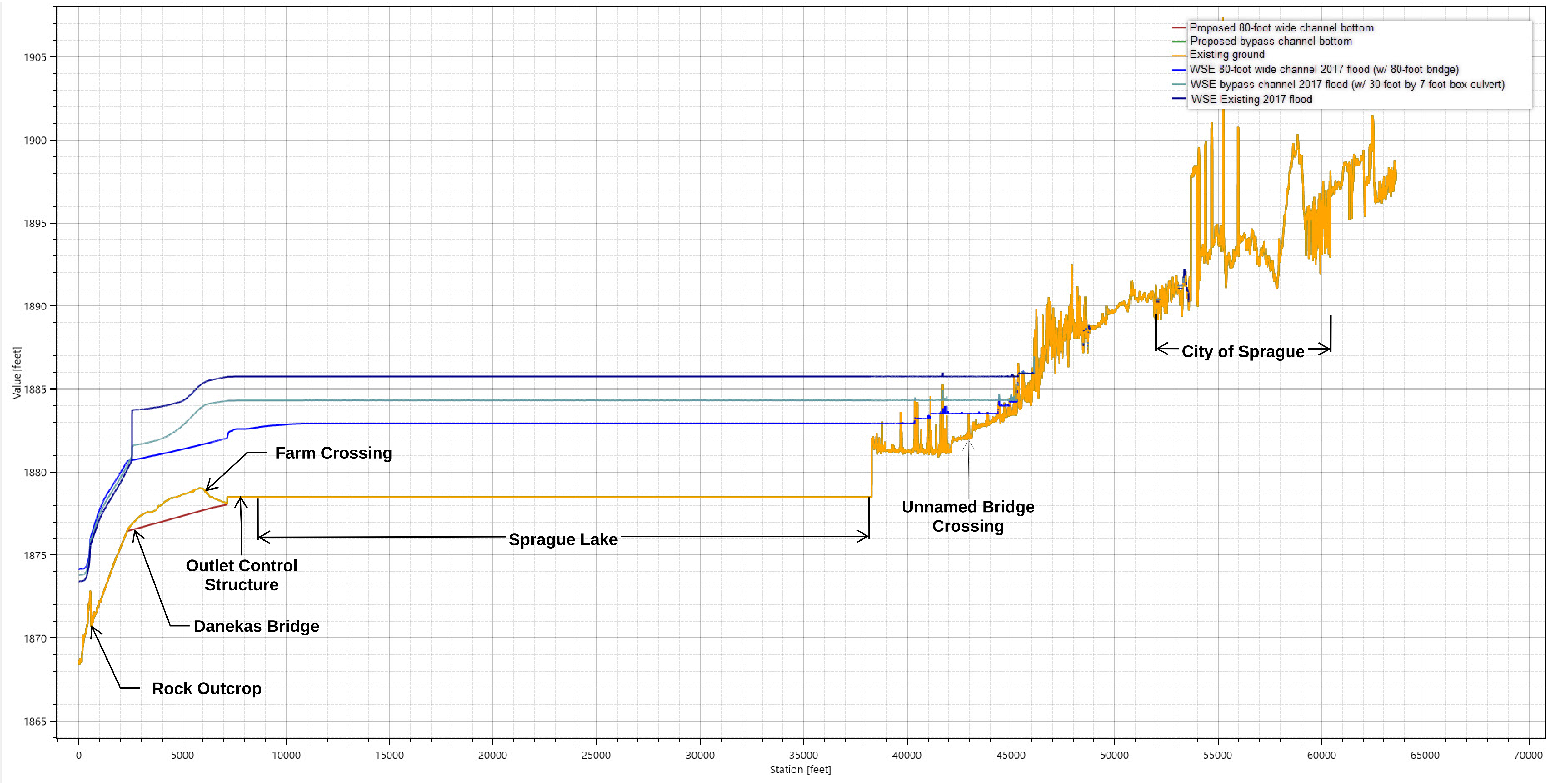
October 2023

**2017 Flood Profile - Peak Water Surface Elevations Large Scale Alternatives**

**Figure 6**



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October 2023

**2017 Flood Profile - 4 Days Following Peak Water Surface Elevations Large Scale Alternatives**

**Figure 7**

# Important Information

## About Your Geotechnical/Environmental Report

IMPORTANT INFORMATION

IMPORTANT INFORMATION

## CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

## THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors that were considered in the development of the report have changed.

## SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events and should be consulted to determine if additional tests are necessary.

## MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

## A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary, because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

## THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

## BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

## READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

**The preceding paragraphs are based on information provided by the ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland.**